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ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY CHAS. COOPER AND J. FOSTER PETREE.

OFFICES FOR ADVERTISEMENTS AND PUBLICATION, 35 & 36, BEDFORD ST., STRAND, LONDON, W.C.2.

VOL. 165—No. 4278 *Registered at the General Post Office as a Newspaper* *LONDON: FRIDAY, JANUARY 23, 1948.* PRICE 1s. 6d. POSTAGE {INLAND 2½d. FOREIGN 3d.

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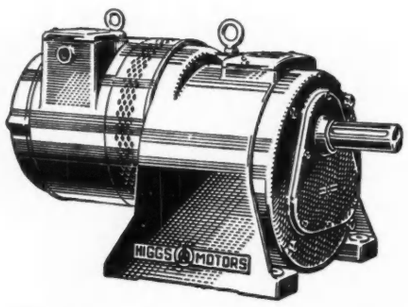

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THE STORY OF ATOMIC ENERGY.

VII.—QUANTUM THEORY AND THE NUCLEAR ATOM.

By DR. FREDERICK SODDY, F.R.S.*

THE period up to the outbreak of the first world war in 1914, to which the last section belongs, embraces also the discovery by Rutherford and his co-workers which led to the recognition of the existence in the atom of a central nucleus of minute size and intense electric charge, out of which arose the present theory of the structure of the atom, usually known as the Rutherford-Bohr nuclear atom. Bohr's contribution, primarily, and still mainly, was more directly concerned, not with the nucleus, but with the electronic outworks of the atom neutralising the nuclear charge, in the familiar field of spectroscopy and ordinary chemistry and physics, rather than with the new sub-atomic phenomena which form the main theme of these sections. On the other hand, the experimental discovery of the nucleus, and its recognition as such by Rutherford, probably advanced the main theme more than any other single new discovery, for it directly opened the door to the achievement, in due course, of artificial transmutation. Coming at the same time as the recognition of isotopes and the Displacement Law, and followed immediately by Bohr's work on optical spectra and Moseley's work on X-ray spectra, it made the nuclear atom instantly acceptable by the whole world of physical science, to mathematicians, physicists and chemists alike.

THE QUANTUM THEORY.

For the origin of Bohr's part of the theory one has to go even farther back than to that of Relativity, to the Quantum Theory, advanced in 1900 by Max von Planck, originally a Dane, born in Kiel when it was in Denmark. This introduced an entirely new conception, which, quite apart from and even more upsetting than Relativity, showed that the laws of classical dynamics, unless profoundly modified, lead to totally false conclusions in the world of rapidly gyrating atoms and masses of that, or lesser, order of magnitude. Unlike Relativity, it received abundant confirmation in the first decade of the century from the most varied branches of the physical sciences, though some of the more important of these are even now only coming into general appreciation. It deals with the most mundane properties of ordinary matter, but in origin is mathematical, rather than physical, and still appears more like a flash of brilliant inspiration than a logical deduction. It was only later that, like Relativity from the start, it began to propound metaphysical conundrums, in the realm of what is known as the Heisenberg Principle of Uncertainty and the Wave-Mechanics. Relativity began by being incredible, and has ended by giving something very matter of fact which it had not been thought possible ever to know. The Quantum Theory gave at once the explanation of a small host of anomalies, but now threatens to make the most familiar phenomena incomprehensible.

Planck's theory began by accounting for the mathematical laws connecting light and heat radiation with temperature, both as regards the quantity and the intensity factors of the energy radiated, for which classical dynamics gives absurd results. It was then applied by Einstein to the explanation of the photo-electric effect, in which light, if of short enough wavelength or of high enough frequency, causes matter to expel negative electrons, and he accurately related the wavelengths or frequencies of the light to the kinetic energy of the electrons expelled. In this field it anticipated by seven years the now accepted view of the nature of the X-rays and γ-rays, that they are forms of light of very short wavelength and high frequency, which was proved in 1912 by Laue, Friedrich and Knipping, of Zürich, and was so ably developed in Great Britain by the late Sir W. Bragg and his son, W. L. Bragg, now Sir Lawrence Bragg. This will be briefly gone into in the next Part.

From 1911 on, Einstein, Debye and others applied the quantum theory to explain the exceptions from the Dulong and Petit Law (1819), that the atomic heats of the elements are approximately six. In the hands of Professor Nernst, of Berlin, the renowned physical chemist, and his co-workers, including F. A. Lindemann, now Lord Cherwell, the specific heat of solids was found to be a regular function of the temperature, characterised by a single constant, the value of which was a property of the particular substance. At very low temperature, the specific heat vanishes altogether. This happens at some 20 deg. C. absolute for the diamond, the greatest exception of all, but is true for all the elements at some lower temperature. As known from the first, for all elements, including the exceptions, the atomic heat tends to become six at high enough temperature, quantum dynamics applying at low and classical dynamics at high temperature for this particular physical quantity, which is a good illustration of the relation between the two systems of dynamics. Its application to the explanation of optical spectra by Bohr and to X-ray spectra by Moseley occurred in the latter half of 1913, and in 1937, M. Polyani, now at Manchester University,

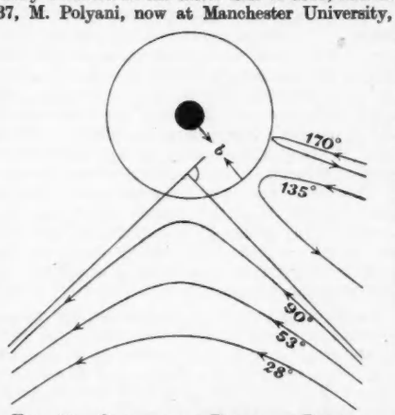


FIG. 44. ORBITS OF α-PARTICLES PASSING CLOSE TO HEAVY NUCLEUS.

showed, as indeed had been suggested much earlier by Lord Cherwell, that it was the key to the understanding of why the lighter isotopes, notably those of hydrogen, can be separated by physico-chemical methods in spite of their complete identity of chemical character. Unfortunately, however, it is even more difficult to give a short intelligible explanation of the quantum theory than of relativity.

ACTION.

The reason is that it concerns a complex technical dynamical conception called Action, of which few have ever heard before in this connection, so that meantime it is advisable to retain the capital "A." It is the strange product of two common enough concepts, usually kinetic energy and time, or momentum and length; that is, it has the physical dimensions $\frac{ML^2}{T}$. It came into use because, with kinetic energy and momentum, it is one of the three dynamical quantities that are conserved in any system isolated from external interference, as for example, a solar system, but its particular use in the quantum theory seems more limited than, for example, in one of its original applications known as the Principle of Least Action, formulated by Hamilton. However, all that is meant by it here is a physical quantity having the dimensions stated.

Its simplest guise is angular momentum, which is, for example, the product of the mass, velocity and radius of orbit of a planet. The principle of its conservation alone is sufficient to deny the possibility of the original nebular hypothesis, proposed by Kant, for the origin of stars. A simple illustration of this conservation is a stone tied on to a string and whirled round rapidly. The string is passed through and gripped with the palm of one hand, held rigidly at the centre of revolution of the stone, and pulled through or let out with the other to vary its length. This causes the velocity of the stone to increase as the string is shortened and to decrease as it is lengthened, the product of velocity and length remaining constant. In this case, the increases and decreases of the kinetic energy of the stone derive from the work done on the stone by pulling it in, and by the stone in letting it out.

The reader must at the start be put on his guard as to one apparent inversion, which may be sufficiently illustrated by the motion of a planet in a circular orbit, the planet, since both gravitational and electrical forces vary as the square of the distance, being either a negative electron moving round a positively charged centre or a planet moving round a sun; that is to say, Kepler's laws apply to either system indifferently, in requiring the velocity of the planet, and therefore its momentum, to be inversely proportional to the square root of the radius, the kinetic energy, therefore, inversely as the radius, while the periodic time, or length of the year for a material planet, increases faster than the kinetic energy decreases, as the square root of the cube of the radius. The consequence of this is that the Action, as above defined, of the planet is directly proportional to the square root of the radius, and therefore increases to infinity as the radius increases to infinity and the velocity and kinetic energy become zero! In approaching the central sun, the Action becomes smaller and smaller as the velocity and kinetic energy increase, and would be zero at zero radius when the speed and kinetic energy become infinite. But for any one orbit, for the Action to be conserved, both velocity and radius must remain unchanged.

This is ordinarily expressed by saying that the planet cannot fall into, or approach nearer to, the sun because, if it did, its velocity and kinetic energy would increase faster than those appropriate to the orbit into which it had fallen, thus causing it, by the excessive centrifugal force generated, to go back to where it was. The same applies if its radius of orbit were to increase. The drain on its kinetic energy in moving out against the sun's attraction would cause it to move too slowly to stay in the more distant orbit, as the centrifugal force would be insufficient to balance the centripetal force. So, again, it must return to its original orbit. But it can equally well be regarded as due to the Action being conserved, though, as already stated here, zero velocity connotes infinite Action and zero Action infinite velocity. This is the inversion that the tyro must be on his guard against, and is usually the greatest stumbling block in giving to the quantum theory any but a mathematical significance. However, it has a cardinal physical significance as will soon appear.

THE ATOM OF ACTION.

What then is Planck's Quantum Theory? In a phrase it is the atomicity of Action. Planck's Constant, always symbolised as h, is the atom of Action, in a sense just as true as that the electron is the atom of electricity. For it is the invariable least quantity by which the Action of a body in gyratory motion can alter, either to increase or decrease, and the Action of any such body must be some integral multiple of h. It is now by far the most accurately known of the natural constants, owing to its close connection with spectroscopy, due to Bohr, just as the wavelengths of certain spectrum lines are the most accurate standards of length. Its magnitude in C.G.S. units is $6{\cdot}625 \times 10^{-27}$ erg-second. It is so infinitesimal that it has meaning only in atomic and sub-atomic motion, for which the Action must be integral multiples of h. It has no application to uniform translatory motion, for which classical dynamics still holds even for that of the minutest particles. The single type of motion the Action of which is atomised is motion in a closed path, the moving body returning to its starting point and original direction after a certain periodic time, whether the motion be of revolution, oscillation or vibration. The shorter the periodic time and the higher the frequency the farther from classical dynamics and the nearer to the new quantum dynamics is the behaviour of the gyrating particle.

* We have arranged with Dr. Soddy to publish his new book, *The Story of Atomic Energy*, in the form of a series of articles which are appearing at fortnightly intervals approximately. Dr. Soddy, however, retains the copyright, therefore no extract may be made from these articles without his permission.—ED. E.

In a planetary atom, such as, to take the simplest case, a negative electron revolving round a positive hydrogen ion, it follows from what has been said that the Action is proportional to the square root of the radius of the orbit. The least possible Action being h, by Planck's Law, h fixes by Kepler's laws the least possible radius of revolution. At any smaller radius, though the kinetic energy increases to infinity as the radius decreases to zero, it is at all times insufficient to correspond to a single quantum of Action, so that now instead of being an inverted way of looking at planetary motion it is the right way. For it explains at once the greatest mystery of physics, why the planets do not fall into the sun, and why the electron and positive ion remain apart and do not instantly recombine to form a neutron or other neutral particle.

It also explains another anomaly. We shall see later that the neutron is such a much more efficient transmuter than the α-particles because of its lack of charge, so that it is not repelled by the positively-charged nucleus as the α-particle is. But, on this logic, the high-speed β-particle ought to be a more efficient transmuter than the neutron, whereas, till quite recently, no such transmutation had ever been observed. Here, as for the hydrogen atom, the two oppositely charged particles cannot unite.

Quants and Quanta.

We have seen that, besides angular momentum, or the product of momentum and length, kinetic energy multiplied by time may equally well be considered the two factors of Action, the time being now the periodic time of the gyrating particle. The inverse of this, or the frequency as the number of times per second the particle completes its closed path, is always symbolised by ν. It thus comes about, more often than not, that the effects are considered not in terms of Action, but in terms of the kinetic energy quantity $h\nu$. Unfortunately, Planck's followers, beginning with Einstein, have got into the habit of speaking of quanta of energy of magnitude $h\nu$. On the modern view that light consists of such discrete quantities, called corpuscles or photons, they speak of light being made up of quanta, but, though no doubt natural originally, this is now confusing even to the trained physicists and, indeed, murders sense. Because the quantum h is in every sense an atom, whereas $h\nu$ is a continuous variable, from zero for translatory motion and increasing without limit as the frequency increases. This misnomer has even led to the muddled idea that energy, not Action, is atomic. In this respect, the writer uses the special word "quant" instead of quantum, for the single factor, usually momentum or kinetic energy, corresponding to the quantum of Action, as will be illustrated later.

The Thomson Model Atom.

The attempt to make the atom obey the laws of classical dynamics was one of the greatest obstacles to progress, for the laws of electromagnetics, if applied to a planetary type of atom, require the electron to radiate light, due to the continuous "acceleration," in direction, not in speed (!), of the electron towards the centre. The writer has never been able to understand why the mathematicians seem to have uncritically assumed that a uniform revolution in a circular orbit was regarded as an accelerated motion in the same way as the change of velocity in a pendulum or other gyratory type of motion, as it seemed a merely canonical confusion between space and time. But few things can be more certain than that the electron in its ordinary motion in the atom does not generate light, as if it did the drain on its energy would make the atom unstable, and the radiation could not be of any definite frequency and wavelength, whereas the latter are among the most fundamental constants of the universe.

Much effort and ingenuity were wasted on this problem in the attempt to stabilise, on the old electrical theory of matter, the electronic system then supposed to constitute the atom. Only the negative electron being known, if the mass is of electrical origin, it requires some 1,845 electrons per unit of atomic weight. In the earliest model-atom on these lines, due to Sir J. J. Thomson, the neutralising positive charge was not atomised, but regarded as a uniform sphere of positive electricity in which the electrons moved, neutralising their negative charge, and which, being diffuse rather than concentrated, did not contribute appreciably to the mass of the atom.

Apart from this, and quite inconsistent with it really, Thomson was the first to put forward an idea that suffices to explain the outer electronic structure of the nuclear atom of to-day, and which was first established by the Displacement Law. It was that the Periodic Law expresses the addition of electrons one by one to the outermost ring until it is full, when a new outer ring is started and the sequence repeated. This simulated very well the periodic return of the elements after a certain sequence to repeat the same sequence, as in the notes of a musical scale, which classifies the elements into families of similar valency and related chemical nature; but it was clearly quite inconsistent with there being 1,845 electrons per unit of atomic mass.

The Discovery of the Atomic Nucleus.

In 1904, the Japanese scientist Nagaoka, put forward the first nuclear atom, in which the positive charge, countervailing the negative electronic charges, was concentrated at the centre, but in absence of any experimental support and being "unstable" according to classical dynamics, the scientific world did not take the model seriously. In 1908, Geiger and Marsden, using the scintillation method of detecting individual α-particles, showed that when these are passed through thin metal foils a few are reflected back—for platinum about one in 8,000 α-particles being turned through more than a right angle. This was the important discovery supplementing Bragg's original conclusion that the α-particles pursue a rectilinear course passing through the atoms in their path almost as if they were not there. In the next year, the scattering of β-rays by matter, which had been systematically investigated by Crowther, led Thomson to the conclusion that on his model of diffuse positive charge there were three electrons only per unit of atomic weight.

In the next year, 1911, Rutherford put forward his nuclear theory of the atom, from experiments on the single or wide-angle scattering, as the reflection effect observed by Geiger and Marsden has come to be called. He concluded it to be impossible that these large deflections could arise as a result of a cumulation of successive small deflections, but must result from a single collision. For the massive α-particle to be so turned back the way it came there must exist in the atom a very much more intense charge than in the Thomson atom, and this charge he estimated as about 100e, in the case of the platinum atom.

It is of interest to recall also that, a little later in the same year, J. W. Nicholson, who also anticipated in an important degree Bohr's theory of spectra, put forward a model atom, with the radius of the positive central charges as much smaller than that of the single electron as the latter is lighter than the atom, so that its mass should be accounted for on the electromagnetic theory of mass. But much of the evidence he adduced from the spectra of certain elements then supposed to exist in the stars but unknown on earth, called coronium, nebulium and protofluorine. This is now known to be false as the spectrum-lines in question have been traced to known elements under peculiarly stellar conditions.

The next year, incidentally, saw the important discovery of what is known as the Geiger-Nuttall relation, which connects the velocity of an α-particle expelled with the period of life of the radioactive atom expelling it, so that if one is known the other can be estimated approximately. The velocity and range are least for the longest-lived and greatest for the shortest-lived α-rayers, and a similar relation, though less definite, has been traced also for the β-rayers.

We now come to 1913, when all the evidence suddenly converged to make Rutherford's nuclear atom model universally acceptable. He published, in conjunction with Geiger, Marsden and Nuttall, the result of an exhaustive examination of α-particles in their passage through matter, showing that there is a slight general scattering of the beam, only aggregating a few degrees of angle, which he ascribed to successive collisions with the very light external electrons, as well as the single scattering, which he attributed to an occasional single collision of the α-particle with the nucleus of the atom penetrated. Fig. 44, on page 73, shows the orbits of α-particles at various angles of grazing incidence on the central atomic nucleus. The diagram has been taken from Lord Rutherford's book *The Newer Alchemy* (Cambridge University Press, 1937). The mathematical theory, for the heavy nuclei, is on much the same lines as that for a comet in its passage at perihelion round the sun, the fact that the forces are repulsive in the former and attractive in the latter making only a difference of sign in the expressions obtained. The various consequences through (1) variation of the thickness of the metal foil penetrated, (2) the velocity of the α-ray, and (3) the atomic weight of the metal bombarded, on the angle of scattering were worked out and tested experimentally with satisfactory agreement. Both these experiments and those on the scattering of β-rays by Crowther were in agreement in showing that the positive nuclear charge and the number of negative electrons in the atom is about one-half the atomic weight. But van der Broek showed agreement was even better if the serial number of the element in the ordinary accepted Periodic Table, now called the atomic number of the element, were taken. This is about one-half the atomic weight at the beginning of the table, but decreases progressively until it reaches about 0·4 for thorium and uranium. But neither this theory, nor that now to be considered had anything whatever to say as to the atomic mass. Only isotopes and the neutron, when discovered, revealed the nature of this somewhat important property of the atom and, as will appear, they revealed everything.

The Rutherford-Bohr Atom.

At this stage, Niels Bohr, a Dane, then at Manchester University with Rutherford, applied quantum dynamics to the nuclear atom model, and was at once able to relate Planck's Constant, h, to a universal purely experimental constant, known as Rydberg's constant, which enters fundamentally into all the expressions for the various series of spectra of the elements. These spectrum series, at that time, had begun to be successfully formulated, first by Balmer, by means of expressions based on what was later termed by Ritz a combination principle.

Spectrum Series.

The first spectrum to be formulated as a mathematical series by Balmer in 1885 was for the ordinary, or vacuum-tube, spectrum given by hydrogen. But his formula for the series gave the wavelengths of the lines, whereas it is more informative to transform his expression to the "wave-number," ν_0, which is the inverse of the wavelength, or number of complete waves per centimetre. This wave-number ν_0, multiplied by c, (3×10^{10}), the velocity of light, is the frequency, ν, or number of complete vibrations per second. In this form the Balmer series is

$$\nu_0 = R\left(\frac{1}{2^2} - \frac{1}{n^2}\right),$$

where R is the Rydberg constant 109,678, and n assumes the successive integral values following that in the denominator of the preceding term (for this case, $\frac{1}{2^2}$, and therefore 3, 4, 5...) to give the wave-numbers of the successive lines starting from the red end of the spectrum. Clearly, as n increases, the successive lines get closer and closer, and, for this Balmer series, end at a wave-number of $\frac{1}{4}$R. This is called the "head-line" of the spectrum, but usually the lines cannot be traced beyond a certain point, owing to their progressive diminution in intensity towards the violet. The first four lines, of wavelengths 6563, 4861, 4340 and 4102 Ångstrom units, respectively, were first observed by Fraunhofer, as the dark absorption lines in the solar spectrum, the first two being lettered C and F by him. In the 1898 solar eclipse, 29 lines of this series were measured.

In 1904, the first line of another hydrogen series in the ultra-violet, known as the Lyman series, was

observed, in which, in the above formula, the first integer 2 is replaced by 1, and the wave-number of the first line, with $n = 2$, is therefore $\frac{3}{4}$R, and of the head-line R, the wavelengths being 1215·7 and 911·8 Å (where Å stands for Ångstrom unit, 10^{-8} cm., the spectroscopist's unit of length). It is very far into the ultra violet, the so-called Schumann region, where only fluorite can be used for the lenses and prisms, and the photographic plates must be made without gelatine; also such rays have to be studied *in vacuo*, as, in this high-frequency region, light has already begun to ionise gases like the X-rays, and so is strongly absorbed even by them. The complete series was predicted, from analogies to other series, by Ritz in 1908, and mapped by Lyman in 1915, after Bohr had explained it. In 1909, the first infra-red series of hydrogen, known as the Paschen series, and in 1922, the second infra-red series, known as the Brackett series, were mapped. In these the integers in the first term are 3 and 4, respectively. It was these series Bohr successfully accounted for by the quantum theory, and, moreover, showed that another series in stellar spectra, taken to be due to hydrogen, was really due to helium, when it was at once reproduced in the laboratory by Fowler. This series had been observed in the spectrum of the star, ζ Puppis.

Bohr's Theory of Optical Spectra.

As has already been indicated, Bohr "quantised" the orbits, permitting the electron to revolve (without radiating) only in those of Action h, $2h$, $3h$, and so on, but normally occupying the first, or No. 1, orbit. Just as in the photo-electric effect, light of high enough frequency will eject from the atom an electron with an energy calculated by Einstein to be the energy of the photon of light minus the energy required to ionise the atom, that is, remove the electron from it, the converse process is the one in which the light originates. The electron, in returning to the ionised atom, will cause the emission of a photon of definite frequency, and this constitutes one line in the spectrum; but complete ionisation is unnecessary. The "excitation" of the atom which precedes the emission of a spectrum line, consists in the removal of an electron from its normal No. 1 orbit to any high-quantum orbit. The emission of the spectrum line occurs when the electron "jumps" back from any outer to any inner quantum orbit. The first integer in the series expression is the number of the quanta for the orbit into which, and the second integer is the number of quanta for the orbit from which, the electron jumps.

As the number of orbits having integral quanta of Action is infinite, the possible number of spectrum lines is more like the second power of infinity, or infinitely infinite, though only a few of these "jumps" give lines of sufficient intensity to be observed. Also, of course, the infinite number of separate series possible in theory start from one definite point in the spectrum and extend successively farther into the infra-red. They so pass from light to infra-red or heat radiation, as in the Paschen and Brackett series, then to wireless frequencies, and so on, and it would be a misnomer to call such low-frequency undulations spectrum lines. The point is that even the simplest possible atom, with one electron revolving round a single positive charge, can give theoretically an infinitely infinite number of spectrum lines, and the complexity of spectra does not, as at first thought, involve an atomic structure "as complex as that of a grand-piano" at all.

The Relation Between the Two Frequencies.

Those wanting the Bohr Theory for use will, of course, be well advised to familiarise themselves at least with the simpler mathematical expositions that have been given in the text-books*; but the main point can be put very simply. Kepler's laws of planetary motion, and Newton's derivation of them from the existence of a central gravitational force exerted by the sun, which varies as the square of the distance from the centre, were, of course, formulated long before the modern conception of energy, just as they were before that of the older conception of Action. But, in terms of energy, a very simple consequence of them is that, in the fall of a planet nearer to a sun, the energy rendered kinetic by the fall is *twice* the additional energy required to maintain the planet in the nearer orbit. Now the material planet has no way, in a system isolated from external interference, of getting rid of this excess kinetic energy, but, for the fall of an electron nearer to the centre of a positively charged atom, the excess is radiated as a single photon of energy, $h\nu'$, where ν' is the frequency of the spectrum line emitted from the atom in the process. This is true for the jump of the electron from any farther into any nearer orbit, say from one of quantum number m to one of quantum number n, where m and n are integers, and m is greater than n. In other words, the energy of the photon emitted, $h\nu'$, is the increase of kinetic energy of the electron in changing from the m to the n orbit. It is very simple to calculate for one case, and that is when the electron in one "jump" falls into the normal No. 1 orbit of a fully ionised hydrogen atom carrying the single positive charge, when, as stated, the head-line of the Lyman series, of wavelength $\frac{1}{R}$, or 911·8 Å, is emitted. In this case, the energy of the photon of that wavelength is the same as the kinetic energy of the electron in its revolution in No. 1 orbit. This enables the radius of the normal No. 1 orbit of the hydrogen atom to be calculated easily from the Rydberg constant. It is $0{\cdot}531 \times 10^{-8}$ cm., which is in excellent agreement with the estimate of the diameter of the hydrogen atom, from a variety of evidence, as being about one Ångstrom unit. This length has been described as the most fundamental unit of length in the universe. The electron normally revolves in this orbit some 600 million times a second.

Simple Derivation of the Spectrum Series Relationship.

The Action, A, or $n\,h$, where n is an integer, of a uniformly revolving body is twice its kinetic energy, E, multiplied by its period of revolution, $\frac{1}{\nu}$, or $A = n\,h = \frac{2\,E}{\nu}$. If q_e is the quant of kinetic energy corresponding with h, the quantum of action, $E = n\,q_e$, which makes $q_e = \frac{1}{2}\,h\nu$. In terms of angular momentum, $A = 2\,\pi\,m\,v\,r$, and q_m the quant of momentum corresponding with h, is $\frac{h}{2\,\pi\,r}$.

For any orbit of Action $n\,h$ and kinetic energy $\frac{1}{2}\,n\,h\,\nu$, by Kepler's Laws, the radius is n^2, the velocity is $\frac{1}{n}$, the kinetic energy $\frac{1}{n^2}$, and the frequency $\frac{1}{n^3}$, in terms of these values for the innermost orbit for which $n = 1$. In falling from an outer orbit of m quanta to an inner orbit of n quanta, the kinetic energy changes from $\frac{1}{2}\,m\,h\,\nu_m$ to $\frac{1}{2}\,n\,h\,\nu_n$, where ν_m and ν_n are the frequencies in the respective orbits. But $\nu_m = \frac{\nu_1}{m^3}$ and $\nu_n = \frac{\nu_1}{n^3}$, where ν_1 is the frequency in the No. 1 orbit. So that the change is from $\frac{1}{2}\,h\,\frac{\nu_1}{m^2}$ to $\frac{1}{2}\,h\,\frac{\nu_1}{n^2}$, and the gain of energy is $\frac{1}{2}\,h\,\nu_1\left[\frac{1}{n^2} - \frac{1}{m^2}\right]$. This is also the energy radiated as a single photon of frequency ν, and energy $h\nu$. Therefore

$$\nu = \tfrac{1}{2}\,\nu_1\left[\frac{1}{n^2} - \frac{1}{m^2}\right],$$

where ν is the frequency of the spectrum line and ν_1 is the frequency of the electron in its normal orbit before excitation. If $n = 1$ and $m = \infty$, we have $\nu = \frac{1}{2}\,\nu_1$, or the frequency of the head line of the Lyman series, $\frac{1}{R}$, is one-half of the frequency of the electron in its normal orbit.

The Rydberg Constant.

The expression obtained by Bohr for the Rydberg constant, R, in terms of the electronic charge, e, the electronic mass, m, the charge on the central nucleus (or atomic number) E, the velocity of light, c, Planck's constant, h, and π, the ratio of the circumference to the diameter of the circle, was, to a very close first approximation,

$$R = \frac{2\,\pi^2\,m\,E^2e^4}{c\,h^3}.$$

A small correction is needed to allow for the fact that the electron revolves, not round the centre of the nucleus, but round the centre of gravity of the system. This correction of R made the theoretical and experimental values of R for hydrogen so close as to be a severe check on the accuracy of the accepted values of the other natural constants, e, m and h, entering into the expression.

The point to notice specially is that the value of R increases as E^2, the positive charge at the centre, which is the same for hydrogen as for the electron. That Bohr was able to associate the series spectrum in the star ζ Puppis, which had been wrongly ascribed to hydrogen, correctly with helium, was due to the value of R being four times that for hydrogen. But this brings in another very important point. E is the *effective* central positive charge, so that the stellar spectrum in question was that given by the doubly ionised helium atom, or helium nucleus, uniting with the electron to form the singly charged helium ion. For the reunion of the electron and the singly charged helium atom to give the neutral helium atom, R has the same value as for hydrogen, since in this case the effective nuclear charge is one, not two.

In optical spectra generally, R has the same value approximately as for hydrogen for arc spectra, as these are due to singly ionised atoms, but for spark spectra, four, nine, or sixteen times as great, according as the spectrum arises from the reunion of the electron with the doubly, trebly or quadruply positively charged ion, respectively. This results in what is called the Spectroscopic Displacement Law, as, allowing for these changes of R, there is a general correspondence between the arc spectrum, for example, of sodium with the first spark spectrum of magnesium, the second spark spectrum of aluminium and the third spark spectrum of silicon.

Before the theory of spectra was understood, these "enhanced" lines, as they were then termed, found first in stellar spectra, and then produced in the laboratory by the spark discharge, with and without Leyden jars in the circuit to augment the temperature of the spark, were thought by Norman Lockyer to indicate that the elements were undergoing evolution at stellar temperatures, the lighter elements condensing into the heavier. But the changes indicated by the changes of the spectrum, from the flame and arc to the spark spectra, are now known to arise from the successive stages of ionisation as more and more of the outer electrons of the atom are shorn off at the increasing temperature, and not to have any transmutational significance.

The Dilemma of Physics.

Bohr's theory of spectra, that light is emitted in the form of discrete packets of frequency ν and energy $h\,\nu$, called photons, has, of course, brought back the old Newtonian corpuscular theory of light, which it was thought last century had been conclusively disproved in favour of the undulatory theory by crucial experiments on diffraction; but, curiously enough, it has not yet, in turn, ousted the latter. As Sir William Bragg put it inimitably, we have to think of light and other forms of radiation as photons on Mondays, Wednesdays and Fridays, and as waves on Tuesdays, Thursdays and Saturdays. This is the present dilemma of physics, though the discovery of the positive electron and the relation between "the electron pair" and the photon, considered later, may now have paved the way to the reconciliation of the two views.

Modern work has revealed that the distinction between waves and corpuscles is becoming shadowy, for the particle has a wave-aspect, and the wave a particle-aspect. Yet common sense demands that there is a distinction, if only because of the clear experimental differences between, for example, the α- and β-particles and the X- and γ-rays, which first led to their identification as particles and waves respectively, and which enable the former to be counted experimentally in various ways, but not the latter. On the other hand, the wave-aspect of the particle has now become quite familiar, through

* Compare *The Structure of Matter*, Appendix, J. A. Cranston, Blackie, 1924. *Radioactivity*, G. Hevesey and F. Paneth, Chapter VIII, 5, Oxford University Press, 1926.

the use of the cathode-rays, that is radiant electrons, exactly as the X-rays for the exploration, by their diffraction, of the structure of crystals and similar regularly orientated molecular structures discussed in the next Part. The only difference is that the former, being very feebly penetrating, the exploration is confined to a surface layer a few hundred Ångstrom units thick.

Prince Louis de Broglie, in 1924, claimed that all moving particles, and especially electrons, had properties analogous to a train of waves, and he predicted this diffraction of the cathode rays as for the X-rays. Further, the electron is now given what is called "the de Broglie wavelength," λ, which is Planck's constant, h, divided by its momentum, i.e., $\lambda = \frac{h}{m v}$. This is usually less than 0·1 Å, and much less than that of any of the X-rays ordinarily employed for the same purpose. Even the neutron is now given this wavelength, and some of the anomalies in its absorption have been attributed to the increase of its de Broglie wavelength with falling speed. On this view, a photon of energy $h \nu$, or $\frac{h c}{\lambda}$, half of which is kinetic and half potential energy, has the momentum $\frac{h}{\lambda}$, and wavelength $\lambda = \frac{h}{m c}$. But the evidence of the particle-aspect of the wave is much less direct and convincing.

LITERATURE.

Wireless Direction Finding. By R. KEEN, M.B.E., B.Eng. Fourth edition. Published for *Wireless World* by Iliffe and Sons, Limited, Dorset House, Stamford-street, London, S.E.1. [Price 45*s.* net.]

THE end of the war left wireless direction-finding in a somewhat tumultuous state, for opposing sides and, to some extent, allies on either side had advanced new systems well suited only to their own particular needs. It is true that several of the systems now widely established and working well on frequencies ranging from medium to ultra-high will be superseded in time by more precise radio-location methods; but radar has its own demerits, especially in its adaptation to the needs of small aircraft. Radar also has a fast-growing literature of its own, so that Mr. Keen has been wise to confine his new writing to non-radar direction-finding methods, for which there is certain to be a demand for many years to come. Paramount needs felt by civilian operators concerned with sea and air transport since 1945 have been for international standardisation of radio navigational systems, and ready access to non-secret but up-to-date information for selective and training purposes. The International Civil Aviation Organisation—and, doubtless, other international bodies—are doing what they can to supply the first need; this book is a generous contribution in aid of the second, and is thus assured of the welcome that its many well written sections quite certainly deserve. To engineers engaged upon direction-finding constructional and maintenance work, and to old hands among sea and air operators, Mr. Keen's comprehensive work will be known already, although its title has been amended twice since the book was originally published in 1922, and it has been out of print since 1943. Students and others wishing to expand and marshal the factual knowledge they have managed to glean from a diversity of sources will be well served, not only by the new sections which have been included in this edition, but also by the pithy historical introduction to the subject and by the orderly chronological development of each modern technique, enabling each to be seen fully and in proper perspective. Moreover, sound practical advice appears when practical matters are being dealt with, while the imagination is stimulated throughout by the admirable use of diagrammatic illustration.

There are indications that the S.C.S.-51—the CAA-RTCA of the United States Army Air Force—already widely used in North America, and officially approved for use in this and other countries of the British Commonwealth, has an international future. The theory and use of this and other approach and landing systems are ably described. Consol, Gee, Loran and Decca are among the systems dealt with which make use of pulse transmission times, or hyperbolic grids overprinted on navigational charts, or both; while systems which make use of special methods for the presentation of bearings, and several wireless beacon systems, the American radio range beacon system among them, are adequately covered. The equipment, organisation and operation of a land-based direction-finding control establishment, which might have police or rescue work as part of its functions, is used as an example of the manner in which duties of this nature, which cannot be performed by radar, might be carried out with maximum efficiency. Various technical aspects of Adcock aerials have been treated in some detail, and the methods of calibrating ship and aircraft equipment have been brought up to date. The application of statistical methods to wireless position-fixing has led to an improved precision in high-frequency work. Fixing by plotting methods based on the principles of least squares and the use of probability ellipses drawn on special graph paper in the evaluation of sets of bearings are dealt with in a new section which considers the operating performance of stations and individual operators, among other interesting matters. Useful chapters deal with such allied subjects as map projection and astronomical navigation; though the last-named section still stands in need of further revision. In so comprehensive a volume as this, six misprints and one badly constructed sentence merely prove the efficiency of all its producers. The book is light and pleasant to handle although it contains well over 1,000 pages; and, if its binding is less robust than the active life of its contents will be likely to require, this may be taken as no more than a sign of the times.

American Arc Welding Patents. Edited by DR. W. H. SIMON. Bailey Brothers and Swinfen, Limited, 11, Ronalds-road, Highbury, London, N.5. [Price 10 gns.]

WELDING is one of those workshop processes which have influenced civilisation to a remarkable extent during the present century, an era of mass production of structural components designed to meet the increasing demands of commerce and industry. Starting from simple beginnings at the close of the last century, the process has become an important factor in the development and distribution of natural resources and manufactured goods by reason of its utility in the construction of motor vehicles, railways and rolling stock, the mechanical equipment of canals, ships, and aircraft. The ramifications are numerous and varied, for they embrace matters of concern in the drawing offices of both mechanical and civil engineers, in time of war as much as in time of peace. A detailed account of the development of welding equipment would involve search of the official patent specifications, and the task would be rendered laborious by the mass of literature to be examined and the fact that relevant patents have often been placed under different headings. For these and other reasons, the book under review should be welcomed by engineers and by patent agents who are interested in the improvement and development of welding equipment.

For such readers, it is hardly possible to overestimate the potential value of this fairly complete record of American specifications concerning arc welding, from 1882 to July, 1945, since the great majority of the entries refer to the time when welding was first established as a standard engineering practice. In addition to abstracts of 1,250 patent specifications, with illustrative diagrams in most cases, it contains complete indexes, under the headings of subjects in the first place, and of patentees or assignees in the second. In the matter of general arrangement, too, the author has taken extraordinary pains to supply essential information, including the date of expiration as well as that of filing each patent; only those who have undertaken such a compilation can have any conception of the prodigious amount of labour involved. Thus the subject-matter lends itself to ready reference, and this is facilitated by the large typewriter face which has been used in printing the text.

A book of this kind merits notice on another basis, since many students of the subject will find in the 574 pages much of interest on the history of an important aspect of engineering science. In the section on welding rods and alloys, for example, it is possible to trace the means by which improvements have been effected in ductility of the weld-metal and in homogeneity of the welded joint. Again, the sections dealing with electrode holders, welding shields, and miscellaneous accessories draw attention to the human factor in the advances made from time to time in this field of enterprise. The work as a whole reflects a constant endeavour to improve the weld as regards porosity, resistance to corrosion, etc., with the ultimate aim of proving that the cost of material, labour and maintenance of arc-welding compares favourably with that of riveting.

The preparation and production of a book on an increasingly important and somewhat specialised branch of engineering such as this, is usually a costly undertaking, for the circulation is necessarily limited, but the price, though high, is justified by the practical value of the information to those who are concerned in any way with the improvement and manufacture of arc-welding plant.

Art and the Industrial Revolution. By DR. FRANCIS D. KLINGENDER. Noel Carrington (Royle Publications, Limited), 29, Percy-street, London, W.1. [Price 21*s.* net.]

THE author of this book has studied deeply the impact of the great economic and social changes of the past two centuries upon the art and the thought of that period; and in it he reviews and describes the interaction of each upon the others, bringing together, as an integral part of his thesis, a striking number of reproductions of illustrations germane to his subject. Some of these have been revealed only as the outcome of the author's own researches, which have been pursued in private as well as in public collections. He traces the great industrial spurt which resulted when the age of timber and charcoal was succeeded by that of cast iron and mineral fuel, coupled with the rise of the steam engine, of the canal system, and of improved road and coastwise transport. He devotes a chapter to documentary illustrations and brings in mechanical drawings, besides marking the effects of the new avenues of artistic reproduction, opened out in the period under review, by coloured aquatint, lithography and photography. The railway has, notably, a chapter to itself. The author has cast his net widely and, while his survey is devoted largely to Great Britain—no doubt because it was there that the Industrial Revolution began. He does mention, among others, the notable work of Pehr Hilliström in Sweden and Léonard Defrance in the Low Countries, even suggesting that they may have been influenced by Joseph Wright, of Derby, whom he acclaims as the first professional painter who expressed the spirit of the new age. The inclusion of an illustration from Hilleström or Defrance would have been welcome; particularly from the former.

The author appends ten pages of valuable notes, a chronological index of the artists, writers, scientists, engineers and industrialists concerned, and a lengthy index, the whole constituting a fully-documented source book which, besides being a delight to the eye, deserves a place on the shelves of every engineer of literary tastes. It is not superfluous, perhaps, to point out a few errors. The Latinised Christian name of Agricola, the author of *De Re Metallica*, was not Gregorius (page 53) but Georgius; the family name of the projector of the New River (page 16) is spelt by the family Myddelton; the older Brunel's Christian name is given as Mark, but he signed himself Marc; Scott Russell's shipyard was at Millwall, not Millbank (p. 128); and the title, "Lymington Iron Works," of Fig. 56, presumably refers to Lemington—though this may be an error on the original engraving.

BRITISH BROADCASTING CORPORATION ENGINEERING RESEARCH STATION.—Kingswood Warren, Banstead, Surrey, with 20 acres of the surrounding ground, has been chosen for use as the principal engineering research station of the British Broadcasting Corporation. It is announced that conditions imposed by the local council include the prohibition of masts exceeding 150 ft. in height and the installation of power plant.

BRITTLE FRACTURE IN MILD-STEEL PLATES—II.

(*Continued from page* 53.)

LIEUT.-COMMANDER E. M. MACCUTCHEON, of the United States Coast Guard, who attended the Conference on Brittle Fracture in Mild-Steel Plates, was invited by the chairman, Dr. (now Sir) A. C. McCance, F.R.S., to give some of his own experiences and those of American shipbuilders and steelmakers. His remarks are reprinted below.

AN AMERICAN POINT OF VIEW.

Lt.-Commander MacCutcheon said: I will try to tell you about some of the work which we have been doing and some of the problems which have faced us. In some of the papers, there is a good deal of emphasis on the sudden failures and the extensiveness of the failures. We have found that not all of the failures are sudden; we have had two or three cases, which have been adequately reported, where the failures have crept slowly across the deck. I remember one instance where the chief engineer of the vessel took an electric drill, went out on deck and tried to drill holes in front of the cracks as they went across. Each succeeding wave caused the cracks to creep a little farther. Later on they abandoned the vessel. Unfortunately, we have been unable to study the fractured edges on plates which have failed in this manner. We do not know whether they exhibit the same appearance that the sudden fractures exhibit. We know that the fractured edges on the plates where the fractures have proceeded quickly seem very similar to those which Mrs. Tipper has already shown, and we have been able to reproduce that on larger plates in big testing machines at the universities of Illinois and California.

In some of the papers, there are remarks about the effects of welding and the effects of continuity. I think that continuity is probably the biggest effect of welding that we have found. The riveted ship has a series of barriers which the crack finds difficulty in crossing. We have found that even a partial weld between two heavy plates, where the penetration may be as little as a quarter of the thickness of the plates, will serve as a link by which the crack can proceed from one plate to the other. That is probably the reason why these failures have been so spectacular. There have been failures in riveted ships, some of them quite serious, but they do not jump from plate to plate as do failures in welded ships.

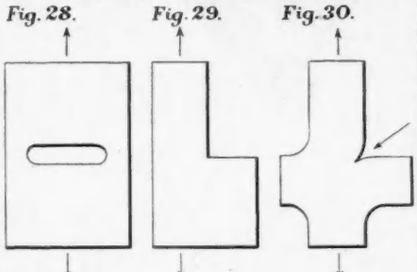
In the United States, there have been about 4,700 ships built under the war programme, and less than 20 per cent. of them have suffered structural failures. I believe about 10 per cent. suffered failures which would be considered serious. The percentage of serious failures is mainly a matter of definition; there can be from 1·7 per cent. to 20 per cent., depending on the definition adopted. The ships have done the job, but there is no doubt that this cleavage fracture problem is a very serious matter. It has meant that the ships concerned have had to be tied up for long periods, and a great deal of money has been spent on their repair. For that reason, the study has been quite intensive. However, in proportion to the value of the ships and the cost of repairs, it has been very modest. It has been considered purely as an engineering problem. For obvious reasons during the war there have been some restrictions on the information. Now that the war is over, the restrictions are being raised on all the data, and reports are coming in without any restriction whatever. The *Welding Journal* (American, of January, 1946) contains a complete list of all the serious fractures, the ships' names, builders, dates, and so on, together with a tabulation of the influencing factors, air temperature, water temperature and other information which was available.

In the beginning, of course, many people were afraid to mention the failures and felt that the matter should be hushed up. I understand that this was particularly so over here. It has not bothered us as much. We have talked about it and spread it around as widely as we could. We thought that we would learn most about the solution by wider circulation of the problem. The question is an engineering one, and cannot be solved in any other way. We have to study it and do tests; so I am going to describe what has been done in the United States.

In the United States, as over here, the investigation began with a great deal of emphasis on welding, locked-up stresses and all kinds of things. We dug into those things and found that the information was very scanty. We thought it best to start investigations on all the branches at once. It is an expensive way to go about any kind of analysis, but there was not much time; and so we put everything on the books immediately and tried to do an investigation of every possible cause. I am sure that we wasted some money that way, because many researches turned out to be blind alleys. Done in proper sequence, some of this work might have been avoided.

Some of the studies have been very fruitful; particularly the analyses of the fractures which have occurred. They have shown us where certain construction faults were and where certain design faults were. There is no doubt that there were some vicious design features in the early ships, and, as Mr. Adam has pointed out, some of the details provided the starting point of many failures. We located the starting points, the design details, poor workmanship, and little fabrication details, but that was evidently not the complete answer. We

Fig. 28. *Fig. 29.* *Fig. 30.*



even improved the ballasting of the ship, and finally we came to the problem of the steel.

Now, before I proceed on the steel problem, I should like to mention the emergency measures which were taken under the pressure of circumstances. We were saddled with all these ships, which were giving us trouble. We were carrying troops in some of them, and the serious consequences of one of those ships breaking in two, with 1,500 troops on board, are immediately evident. We had to take some measures, therefore, to insure ourselves against a catastrophe of that nature. We took a rather bold step; we put in what we called crack arresters. Everybody has been trying to read our minds about these things, but they were intended as crack arresters and nothing else; if they did anything else, we did not intend it. There has been a great deal of talk about flexibility in connection with crack arresters. Maybe they do add to the flexibility and maybe they do not; we do not know; but they are crack arresters, anyhow. The idea was to cut a slot and put a riveted strap over it. This broke the continuity of the structure so that when the crack came to the slot it would stop—we hoped. We have already fitted these on 35 per cent. of the Liberty ships. Several ships have demonstrated the performance of the crack arrester. It is reported that the crack arresters were effective.

The crack arresters were a temporary measure, however. It is not the Government's policy or anybody else's policy in the United States to continue to fit these straps. We hope that, in the future, we shall be able to build successfully all-welded ships. However, we have informed our shipbuilders that, until we learn more about steel, we are not going to go ahead with it, and that we shall continue to ask for riveted gunwale bars to serve as crack arresters.

Coming now to the steel study which we have made, I think we came around to it a little before you did. We had already succeeded in performing some tests in which we produced fractures similar to those described by Mrs. Tipper. We did them on a larger scale, and we did not know whether we could do it on a small scale. We presented the steel people with the data, and we pointed out to them that it was not the quality of the steel which was in question. We had already demonstrated that the steel was up to existing specifications, and there was no question on that score. We had made a random selection of steels from our shipyards, and, out of 257 plates, 92½ per cent. met the American Bureau of Shipping requirements for ultimate strength. That was good, because the acceptance test, as you know, may be taken out of almost any part of the plate. We chose other parts at random, so that naturally there was a little spread; Mr. Barr reports an American plate with 21 tons per square inch ultimate. This was a surprise to me.

In order to handle the programme of steel studies, we first rolled two, and then later five, special heats of steel, covering a range of notch sensitivities. Our steel people assisted in preparing the specifications for these heats. Apparently they did very well, because your results here on these few tests do not cover anywhere near the range that we were able to get. Unfortunately, our figures are expressed in degrees Fahrenheit. The mills rolled one rimmed steel which exhibited notch sensitivity above about 120 deg. F., and they rolled a fully-killed steel which had a similar transition range below 0 deg. F. We do not use the Izod test very frequently; we use a Charpy bar with a V-notch, and that is what these figures are quoted on.

The programme at present involves four laboratories. We are making use of large testing machines at Illinois and California, and we have one laboratory which is to study the possibilities of getting a specimen which we can use for classifying steel. That is under Dr. Gensamer at Pennsylvania State. The fourth laboratory is the U.S. Navy's Taylor Model Basin in Maryland. We have already discussed the possibility of changing specifications on the basis of these tests, and that has been received quite agreeably by all hands. I believe that, sooner or later, we shall have new specifications, and it has even been suggested that we should adopt an interim specification and shut out the worst steels right away. I have a suspicion that we are already getting better steel.

I am going to give you a little summary of what we are doing in the way of tests. I have already told you that we have a great variety in the steels. We do not know the fundamental reasons for these differences. Evidently, as has already been brought out here, manganese has something to do with it. Our steelmakers presented us with one heat of steel which is, I should say, very close to the British steel, higher in manganese and lower in carbon, and it gave about the same result as your tests indicated; it is better than our average semi-killed steel.

We have used something like eleven different specimens, and, since ours are a little different from yours, I shall give sketches of them. We do not use the Izod very frequently. We have used a V-notch and a keyhole, and we are testing to find which is more reproducible. Apparently the keyhole is a little more reproducible, but some people prefer the V-notch. Most of our tests are being conducted on plates with an internal notch (Fig. 28). I do not know whether there is any wisdom in this, but in Mrs. Tipper's tests, when fracture starts on one side, it goes all the way to the other. With the internal notch, when one side starts the redistribution of load starts the other side. We are now testing specimens 3, 6, 12, 24, 48 and 72 in. wide, and most of the work at present is being done on ½-in. plate.

In addition to that, we went one step farther and tried a fabricated specimen (Fig. 29), weighing about 2 tons. It is fabricated with a hatch-coaming and everything else, similar to the Liberty-ship hatch corner, but the plate thicknesses are all ½ in. We did not have a variety of thicknesses in our various types of test steel, but used one thickness almost throughout. We have tried several different types of steel with this specimen and it is the most severe specimen by far. The internal-notch type gives a transition for a fully-killed steel below 0 deg. F. and this gives above 32 deg. F. for the same steel.

The University of California tried one crazy-looking specimen (Fig. 30) which will also give transitions comparable to the hatch-corner specimen.

The crack starts where indicated by the arrow. It is obvious that the type of specimen has a real influence. We are trying now, by getting a whole lot of information on different sizes of specimen. We hope to get enough data to interpret the meaning of these Charpy V bars, and so on. It is too bad that we cannot just take a little cube and pull it in three directions, because that would save a lot of trouble.

There is another matter in which I think you will be interested because I do not think that it has been mentioned in connection with your investigations. I referred to the crack which went across the deck slowly. We tested some of the specimens of our fully-killed steel and our rimmed steel, with an internal notch cut with a jeweller's saw, and at a nominal stress of + 16,000 lb. to — 16,000 lb. alternating stress, and also over a range of temperatures. On the basis of starting and extending a fatigue crack to 0·6 in. length, we found that, with this type of loading, the temperature does not have much effect; but the fully-killed steel normalised stood up better under that test than the rimmed steel, either as-rolled or strain-aged. We were glad of that, because it would be bad if the steel resistant to the one type of loading was not resistant to the other. We should not have been able to choose a good steel if we found that the fully-killed steel was resistant to the quick fracture and the rimming steel to the slow.

We are hoping to get three things from our study. First of all, we want to get a specimen for grading steel. Second, we want to get a better steel. I think we already know how to do that, but we want to do it without a 30 per cent. extra cost; maybe we can do it with the aid of a little manganese. Third, we want to know what liberties we can take in the repair and fabrication of ships built of the steel which we already have. Even if we get a better steel, we still have 4,700 ships to deal with, so that we have to know more about the steel we are now using.

My tour round the British shipyards has helped me a great deal, because I have seen that you are not having the troubles in fabrication that we are, and evidently that is due to the steel. If you imagine it is in the shipyards you are wrong; the only difference must be the steel that you use. You use the same electrodes and essentially the same welding procedures. We are putting a good deal of emphasis on sequence and procedures. Your shipyards are not taking as much care of that as ours. There must be something else to explain it, and I think that steel is the answer.

(To be continued.)

THE "MAXIGRIP" UNIVERSAL CLAMP.

THE difficulties experienced in clamping awkwardly-shaped parts to the work tables of milling, shaping and similar machines are well known. In many cases special jigs or clamping fixtures have to be made and when the number of parts to be machined is small this adds materially to the cost. The necessity for manufacturing such jigs, however, can be reduced considerably by using a new clamping device known as the Maxigrip, which has been introduced recently by Messrs. Adam Machine Tool Company Limited, Acme Works, Waverley-road, St. Albans, Hertfordshire. These clamps have been designed to replace the use of heavy machine vices on the work tables of milling and similar machines, and to hold parts of an awkward shape to the face plates of heavy lathes. A clamp suitable for the latter purpose is illustrated in Fig. 1, on this page, while Fig. 2 is a diagrammatic sketch showing a typical part held to the face plate of a lathe by three clamps.

Several types of clamp are available, the main difference between them being the method by which they are held to the work table, the clamping action being the same in each case. The method by which the clamping action is obtained will be clear from a study of Fig. 1. Each clamp consists of three main components, namely, the body, the jaw and the jaw screw and, in the clamp illustrated in Fig. 1, the body is secured to the lathe face-plate or the work table by T-headed bolts and nuts. The jaw is held to the body by a socket-headed set screw which is threaded into a tapped hole in the body of the clamp, a light coil spring being interposed between the underside of the jaw and its seating. It will be seen from Fig. 1 that the rear face of the jaw, which is set at a slight angle to the longitudinal axis, has machined on it a series of parallel teeth and that these teeth mate with slots machined on an inclined plane formed on the body of the clamp. It will be clear that when the set screw is tightened, the rear of the jaw will move down the inclined plane and consequently will be displaced towards the front of the clamp. In use, therefore, the clamps are adjusted as closely as practicable to the workpiece and bolted securely to the table, the workpiece being then gripped by tightening the setscrews.

As previously mentioned, several different types of clamp are available, the difference between them being the method employed for securing them to the work-table. The range of clamps includes those with the bases machined in the form of a T, either parallel or at right angles to the face of the jaw for sliding into the slots provided on practically all work tables.

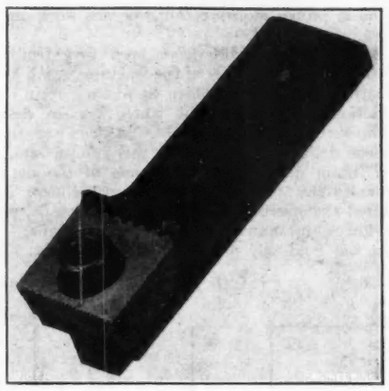
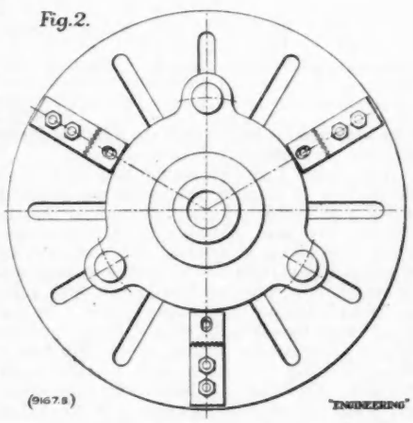


FIG. 1.

Fig. 2.



Another type has a body similar to that illustrated in Fig. 1 but is fitted with a single T-headed bolt, the nut of which is shallow and sunk into the body of the clamp. By adopting this form of construction, that part of the clamp projecting above the work table is reduced to a minimum and it can be used, therefore, to hold shallow components to the worktable while allowing the cutter to pass over the clamp.

Obviously the clamps have many potential uses and can be employed in conjunction with existing jigs and fixtures. Their use, however, is by no means confined to machine tools; for example, the clamp illustrated in Fig. 1 is also supplied with a flat base, and this type might well be bolted to a workbench and used for holding awkwardly-shaped parts during marking out or other manual operations.

THE CENTENARY OF ELSWICK WORKS.—The Elswick works of Messrs. Vickers-Armstrongs Limited, was founded in 1847 by W. G. Armstrong and Company to produce the hydraulic cranes invented by William (afterwards Lord) Armstrong. The manufacture of ordnance, under Armstrong's patents, began in the Crimean War; shipbuilding was added to the company's activities in 1868; and steelmaking in 1884. These are the key dates in the development of the works, but there were many intermediate and subsequent extensions in the range of their products, all of which are succinctly described in the commemorative brochure issued by the firm in December, 1947, to mark the centenary. The authorship is anonymous, but the compiler evidently has a long and intimate personal association with the works.

OIL DETERIORATION IN TRANSFORMERS AND SWITCHGEAR.*

By H. HURWORTH.

BOTH engineers and chemists agree that oil deterioration accelerates rapidly with age. The reason for this is still uncertain, although the initial slowness of the process has been attributed to inhibiting substances which exert a powerful retarding action on the oxidation of the new oil. Acid refining removes both sludge-forming substances and some of the natural inhibitors. There is recent evidence, too, that these substances are sulphur compounds; and that their addition to the oil after it has received strong acid treatment greatly increases its oxidation stability. Evidence has also been accumulating to support the opinion that the oxidation processes are auto-catalytic. For instance, an examination of the acidity records of the transformers used in the Leeds Corporation Electricity Department has shown that the annual growth in the number of cases in which the acidity value of the oil exceeds 1 mg. of caustic potash per gram can be represented by a straight line on a logarithmic scale; and that the rate of increase can be expressed by an equation which represents the auto-catalytic type of growth. Analysis of a curve of increase in acidity of grade A oil in a transformer with more or less constant load also showed that, after four years, the curve changed suddenly from a logarithmic to a linear characteristic, and that the new rate of increase was constant. This termination of the logarithmic-rate curve may be caused by a shortage of oxygen. Since, as the oil ages and there are more deterioration products to produce auto-catalytic action, more oxygen is required to support oxidation. Consequently, there is a greater friction loss in the breathing orifice through which air enters the tank and a reduction in the oxygen pressure in the oil. This process continues until nearly all the atmospheric pressure of the oxygen is utilised in overcoming friction losses. The maximum amount of oxygen is now entering the transformer, and the rate of oxidation has reached a peak value which is associated with the linear part of the curve.

According to the above theory, the oil will have a longer life if the linear part of the acid curve is reached while the rate of oxidation is still low. This can be achieved by increasing the friction losses in the orifice, expansion chamber and oil. By suitably designing the transformer, it is possible to do this in each of these places, but, to obtain the maximum benefit, each stage requires separate consideration. The oxygen flow through the orifice is impeded by friction from the sides of the openings. A high friction loss therefore requires a long orifice and a small area. A wide shallow orifice provides more friction than a circular one of the same length and area. The steepness of the gradient is also influenced by the presence of other gases in the orifice, which occupy space that would otherwise be available for the oxygen. This has to be compensated by an increase in the velocity of the oxygen, which causes higher frictional losses and a rise in the pressure-gradient. The gases and oil vapour which occupy the air space between the oil surface and the breathing orifice, also resist the flow of oxygen and thus contribute to its pressure-gradient. The amount of oxygen pressure lost in overcoming friction varies with the depth and cross sectional area of the expansion chamber.

Chemical reaction between the oxygen and oil vapour also contributes to the pressure-gradient and increases with the temperature of the gases, the height of the expansion chamber and the potential-gradient of any electrical stress applied to the gases. The effect is also proportional to the oxygen concentration. The fall in pressure due to friction is directly proportional to the depth of the chamber, but that caused by chemical reaction is steeper near the breathing orifice than it is near the oil surface. The combined effect is that progressively increasing the depth produces a smaller and smaller bonus. A test showed that the reduction in acidity produced by increasing the depth four times was 20 per cent.; and this result was not altered by introducing a heat cycle. The expansion and contraction of the oil associated with the heat cycle are responsible for a pumping action, which is exerted on the contents of the air space. This forces out the contaminated air and draws in air containing a higher proportion of oxygen, thus increasing the average oxygen pressure inside the transformer. The increase in acidity caused by one heat cycle a day has been shown by test to be about 50 per cent. This result is not influenced by the depth of the air space.

Liquids resist the flow of gas very much more than gases. Consequently, in a transformer the oxygen pressure gradient in the oil is more influenced by oil movement than by natural diffusion processes. According to the empirical values, only 8½ per cent. of the gas molecules have a penetration rate exceeding

* Paper read before the Transmission Section of the Institution of Electrical Engineers on Wednesday, December 10, 1947. Abridged.

0·5 in. per hour. By comparison, convection currents moving at a few inches per minute can distribute oxygen very rapidly indeed. Taking into account that the oxidation rate varies as a power of the oxygen pressure, it is evident that, in the absence of convection currents or mechanical agitation, practically all oxidation will occur in the surface layers. In a deep tank, deterioration will therefore be a very slow process. In conservator transformers the upper layers of oil are screened from convection currents, and the oxygen gradient is therefore steep. In non-conservator types, however, where the whole of the oil is circulated, the velocity of the convection currents may be high enough to obscure the effect of diffusion; and there may be practically no gradient.

The physical properties of oil concerned with convection are the coefficient of expansion and the viscosity. Expansion is responsible for the change in density which causes the movement, while viscosity is a measure of the restraining force. Purely from the point of view of oxidation stability, transformer oil should, therefore, possess a low coefficient of expansion and a high viscosity. Any improvement in the life of transformer and switch oils gained by increasing the viscosity may be balanced by an increase in the winding temperatures and switchgear arcing limits. The effect of winding temperatures may, however, not be as great as first considerations suggest, because the improvement in stability will retard the formation of sludge deposits on the windings and delay the onset of the resulting temperature increases.

One way of restricting the influence of convection currents in non-conservator transformers is to isolate them from the oxygen-saturated surface layers of the oil by a barrier in which a hole has been drilled to allow the oil to expand or contract. Tests show that the oil then circulates fairly rapidly in the shallow space above the barrier, as well as on the under side. This shows that the oxygen pressure is fairly evenly distributed in the areas above and below the barrier; and that the lower acidity of the oil found in the barrier cell is due to a sharp fall in the oxygen pressure across the depth of the barrier aperture, a distance of only $\frac{1}{8}$ in. This conclusion emphasises the importance of the oil path by which oxygen diffuses into the main tank of a transformer, and the advantages which can be gained by restricting its area and increasing its length. The small pipe connecting the main and conservator tanks on all conservator-type transformers obviously fulfils these requirements most efficiently. Probably most of the oxygen entering the main oil tank of a conservator transformer does so as a result of the contamination produced by the action of the heat cycle. The process is similar to that occurring in the expansion chamber. Oxygen-free oil from the main tank is pumped into the conservator tank and mixed with oil which is almost saturated with oxygen. When the oil cools, it is returned to the main tank contaminated with oxygen. The amount of oil concerned in this transfer varies with the coefficient of expansion of the oil, with the range of temperature and with the frequency of the heat cycles.

From a consideration of the peculiar arrangement of the deposits sometimes found on the insulated stalks of oil circuit breakers, it may be assumed that deterioration products tend to concentrate in the areas of greatest electrical stress. There is no doubt that, in certain circumstances, this tendency influences the rate of deterioration. Such deposits, however, are only found when the oil remains undisturbed for a long time, while convection currents assist the natural processes of distribution and oppose the tendency to concentration. Apparently a very small amount of heat is sufficient to destroy this evidence. The periodical inspection of oil circuit breakers has shown that in every comparable instance oil deteriorates more rapidly in circuit breakers remaining for long periods in the open position than it does in similar breakers under load.

For several years it has been standard practice on a large distribution system to make detailed reports of any sludge deposits found in transformers or switchgear. These reports, which cover nearly 2,000 units, show that in no instance has sludge been deposited above the oil level unless the oil vapour has been subjected to electrical stress. This evidence leads to the conclusion that the quantities of sludge deposits on transformer lids and circuit-breaker insulators are too large to be deposits of volatile sludge formed by chemical action below the oil surface. It may be concluded also that the number of chemical reactions produced in the oil vapour by molecular agitation at normal transformer temperatures is insufficient to produce noticeable quantities of acid or sludge; and that a satisfactory explanation of both corrosion and heavy deposit is to be found in the action of electrical stress on the oil vapour. A more detailed examination has been made therefore to discover whether any relationship can be found between the amount of sludge or corrosion and the potential gradient. Analysis of the results indicates that some kind of relationship does exist. For example, heavy deposits are found only in the older types of switchgear, where all the electrical clearances are small and the insulators short. It has also been noticed that a high stress gradient in the oil expansion chamber and a heavy vapour concentration, caused either by a high operating temperature or restricted breathing, are always associated with heavy sludge deposits or lid corrosion.

An example of the effect of electrical stress on the deterioration of oil vapour is provided by a case where the potential gradient in the oil space of a transformer was increased to about 4,000 volts per inch—or three times the normal value—by a fall of 2 in. in the oil level. Apparently, the air space had been subjected to this stress for some months. The transformer contained grade A-30 oil, which was fairly clear and light brown in colour. The tank lids and walls were heavily sludged with a dark brown deposit, some of which had fallen on to the insulators and live conductors. The lid and thermometer tube were badly corroded, several holes appearing in the former when the transformer was moved. A green deposit which was removed from the thermometer tube showed strong traces of copper formate. The sludge deposits were heavier and the corrosion worst on the coolest parts of the tank, owing apparently to condensation. The transformer had been operating with a fairly high ambient temperature, while the normal load averaged 60 per cent., and was maintained fairly steady for eight hours a day. The situation was dry and the operating conditions were normal.

An examination of the deposits on transformer lids has sometimes shown rather strong concentrations of ferric or iron formate. These deposits indicate that the oil vapour contains fairly large quantities of mobile ions in the form of volatile acids, which may contribute substantially to the stress activity. Perhaps more important, however, is their tendency to orient in the stress field, thus reducing their chances of escape through the breathing orifice. The escape of the oxidised vapours is also influenced by the temperature of the transformer cover plate. Parts of the plate are often much cooler than the oil, and molecules of formic acid and water vapour readily condense on them in a highly corrosive form. This condensation can be reduced by using gaskets with good heat conducting properties and thus increasing the temperature of the lid. Ventilation also reduces the acidity and almost eliminates lid corrosion. It has, however, the disadvantages of not retarding the absorption of oxygen and of entirely eliminating that part of the oxygen pressure-gradient above the oil surface. As a result, the oxygen pressure in the surface layer of the oil is raised to atmospheric pressure, and the rate of deterioration is greatly accelerated. Furthermore, ventilation practically eliminates any chance that the oxidation rate will become stabilised before the oil becomes useless as an insulating medium.

It is concluded that the useful life of insulating oil in transformers can be increased by modifying the design with the object of increasing the oxygen pressure-gradient. The best way of doing this is to provide a barrier just below the oil surface, while further improvement can be obtained by increasing the depth of the expansion chamber or reducing its cross sectional area. It is believed that the practice of removing corrosive volatile acidity by ventilating the oil expansion chamber is not the best way of solving the problem and will shorten the useful life of the oil. There is evidence that the electrical stresses above the oil surface, acting upon the oil vapour, may be responsible for a high proportion of the total deterioration products. It is also probable that the orientation of volatile acid molecules under electrical stress causes them to be retained inside the transformer instead of passing out of the breathing orifice with other less harmful vapours. On these grounds, stresses in the oil expansion chamber should be avoided. The ejection of corrosive vapour is also retarded by condensation on cold transformer cover-plates. Lid gaskets should therefore be made of heat-conducting materials.

While the Michie sludge test takes into account the effect of any variations in the solubility of different samples of oil at the test temperature of 150 deg. C. (if oils have different solubility/temperature characteristics they may show equal stability at 150 deg. C.) yet one oil may be much better than the other at service temperatures of 50 deg. to 80 deg. C. Consequently, if it is considered desirable to define a limiting value for solubility it should be expressed in terms of the working temperature. The British Standard Specification assigns a maximum value for "viscosity" with the object of ensuring efficient oil circulation, a high viscosity being associated with a high winding temperature. It is suggested that the advantages of increasing the existing maximum should now be given consideration, in view of the relationship between viscosity and oxygen pressure-gradient. It might be worth a slight sacrifice in winding temperatures to prolong the life of the oil. Any new value should, however, be expressed at the working temperature.

150-TON STRUCTURE-TESTING MACHINE.

MESSRS. W. AND T. AVERY, LIMITED, Soho Foundry, Birmingham, 40, have recently constructed a testing machine for Messrs. Short and Harland, Limited, Belfast, which is designed to subject structures to a maximum compressive, tensile, or bending load of 150 tons. The machine is in two main parts: one for tensile tests of structures up to 9 ft. 9 in. in length between the connecting pins; and one for compressing structures not more than 15 ft. in length, or for applying a bending moment over a maximum span of 7 ft. The compression and bending unit is shown in Messrs. Avery's works in Fig. 7, and the tensile unit in Fig. 8, on page 84. General arrangement drawings of the whole machine are reproduced in Figs. 1, 2 and 3, on page 80.

The machine has been designed to avoid obstructing the specimen, and it thus allows a stress-strain analysis to be undertaken, using suitable gauges. By testing a specimen in the vertical position, the effect of its weight is reduced. In the past, models have often been used for testing the design of a structure, but this machine is intended for testing full-size specimens. It is usual to construct a testing machine with accommodation for the tension specimen below, and the compression specimen above, a central crosshead, which applies the load; but it was not possible in this case, owing to the combined length of the specimens. The separate units have the further advantage that a test may be in progress in one, while a specimen is being set up in the other. The testing of long structures in compression introduces the problem of side thrust due to eccentric loading or the collapse of the specimen under load. Side thrust can cause errors in the measurement of the load, and the compression unit has therefore been designed to avoid this. The two main units of the machine are served by a common hydraulic pump, which supplies oil under pressure to either unit, and by a load-indicating and control cabinet, situated between the main units, as shown in Fig. 2. The cabinet is illustrated in Fig. 5, on page 81.

The tension unit consists of a cast-iron base; four steel columns surmounted by a hydraulic cylinder and ram; an upper crosshead connected to the ram; a lower crosshead for applying the load to the specimen, and connected, for this purpose, to the upper crosshead by two rods; and a platen which may be fixed at any convenient height to suit the length of the specimen. The cylinder and ram contain no packing, which, owing to friction, would increase the oil pressure required for a given load and thereby introduce an error in the indicator. They are therefore machined to close limits for a length sufficient to form an effective oil seal. The upper crosshead rests on a ball seating on the ram, which has a stroke of 20 in. There is also a central bolt which transmits the recoil of the crossheads and connecting rods when the specimen breaks, the shock being absorbed by the suction of the ram on the oil in the cylinder. When a specimen breaks with the ram almost at its full extension, the recoil is absorbed by a wooden block. Two shackles, one in the lower crosshead, and one in the platen, are provided for connecting to the specimen; and the distance between the centre lines of the shackle pins (with the ram not extended), may be fixed at intervals of 12 in., between 9 in. and 9 ft. 9 in. The platen is raised or lowered by a 2-ton pulley block, and fixed by detachable shear collars which engage grooves in the four columns. The gap between adjacent columns is 3 ft. $2\frac{1}{4}$ in. in one direction and 2 ft. $8\frac{1}{2}$ in. in the direction at right angles.

The compression and bending unit consists of four fabricated steel columns; a hydraulic cylinder and ram (similar to those in the tension unit), mounted in the base; a lower moving platen, connected to the ram; an upper platen, adjustable to suit the length of the specimen; an observer's platform; and a winch at the top of the unit for raising and lowering the upper adjustable platen. The general construction of the lower platen will be apparent from Figs. 1 and 2, and from the photograph reproduced in Fig. 4, on page 81. The hydraulic cylinder rests on a ball seating in the bed of the unit, and there is another spherical seating between the ram and the lower platen. Sixteen roller bearings (four on each side), mounted on the lower platen and the cross-braced frame below it, guide the platen by rolling on the machined faces of the four columns. The lower group of roller bearings may be adjusted by means of screws and collars, visible in Fig. 4, to tilt the platen up to $\frac{1}{2}$ deg. in any direction, to allow for the ends of the specimen being out of square, and to obviate the use of shims. Fig. 4 shows three 50-ton proving rings inserted between the platens for calibrating the machine. The columns are of fabricated box section to ensure lateral stiffness; and, in combination with the spherical seatings of the cylinder, ram and lower platen, the design minimises errors in load measurement caused by eccentric loading of the specimen.

150-TON STRUCTURE-TESTING MACHINE.

MESSRS. W. AND T. AVERY, LIMITED, BIRMINGHAM.

Fig.1.

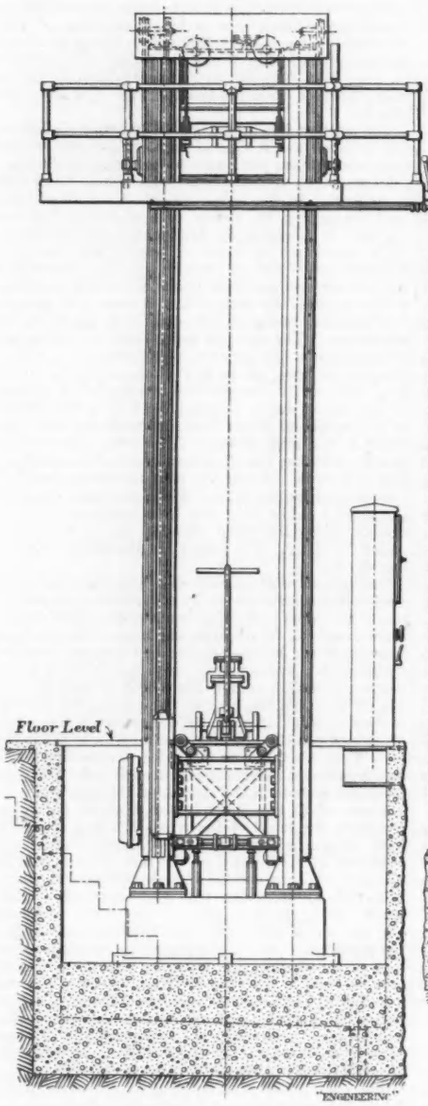
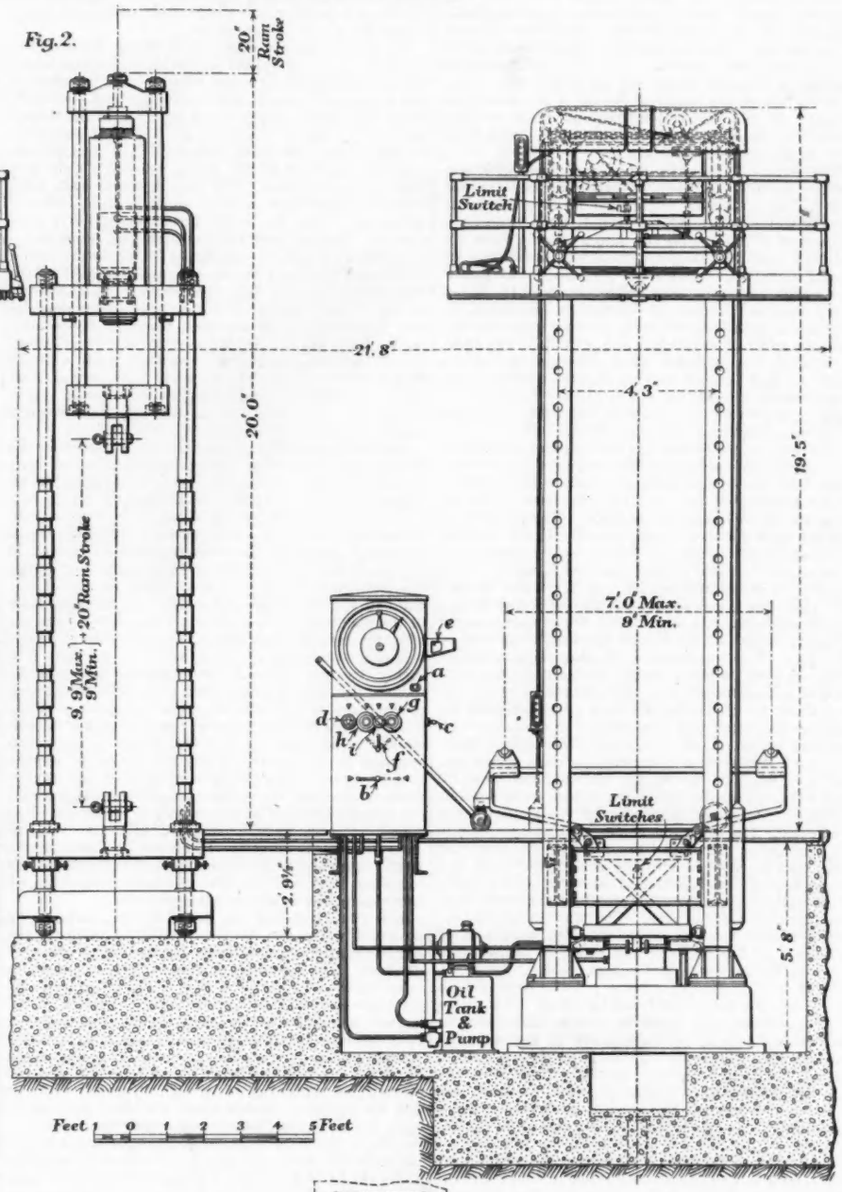
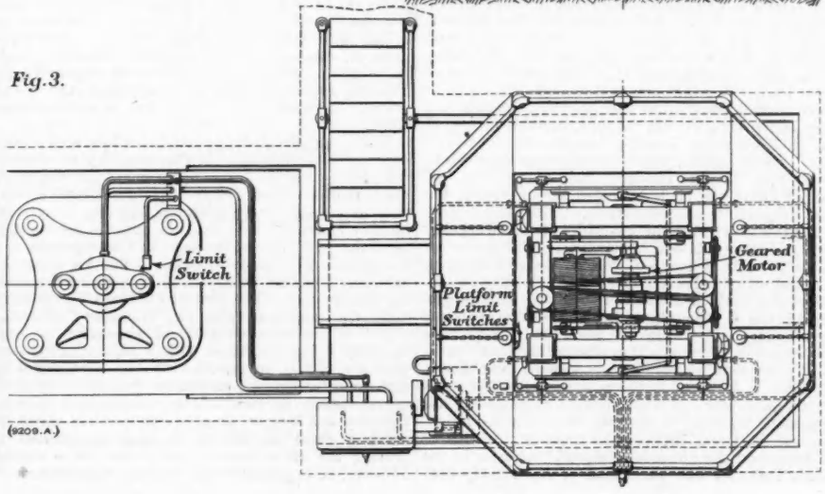


Fig.2.



The top compression platen may be fixed at intervals of 12 in. between 15 ft. and 12 in. from the lower platen. It is guided by the four columns, and is locked in position by four shear pins which engage holes in the columns, as shown in Fig. 4. A 1-h.p. electric motor drives a winding drum through gears, to raise and lower the platen. A group of five push-buttons ("hoist," "lower," "inch up," "inch down," and "stop"), is provided at floor level, with a duplicate set on the observer's platform, to control the adjustment of the upper platen. With the "inching" buttons, it is quite easy to adjust the platen to an exact position for locking the shear pins. An electro-mechanical brake on the motor shaft limits over-run, and cut-out switches are fitted at the upper and lower limits of the travel of the platen. Two bars (one of which is visible across the top of the shear-pin handles in Fig. 4) are arranged to move up and cut out the hoisting motor whenever a shear pin commences to engage a hole in one of the columns. It is therefore impossible to start the winch motor when a shear pin is engaged. Both platens are 3 ft. square, and are provided with tapped holes to accommodate clamping plates, or other fixtures for securing the specimen. The gaps between the columns are 3 ft. 3 in. by 2 ft. 9 in. The observer's platform surrounds the four columns, and is counter-

Fig.3.



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150-TON STRUCTURE-TESTING MACHINE.

MESSRS. W. AND T. AVERY, LIMITED, BIRMINGHAM.

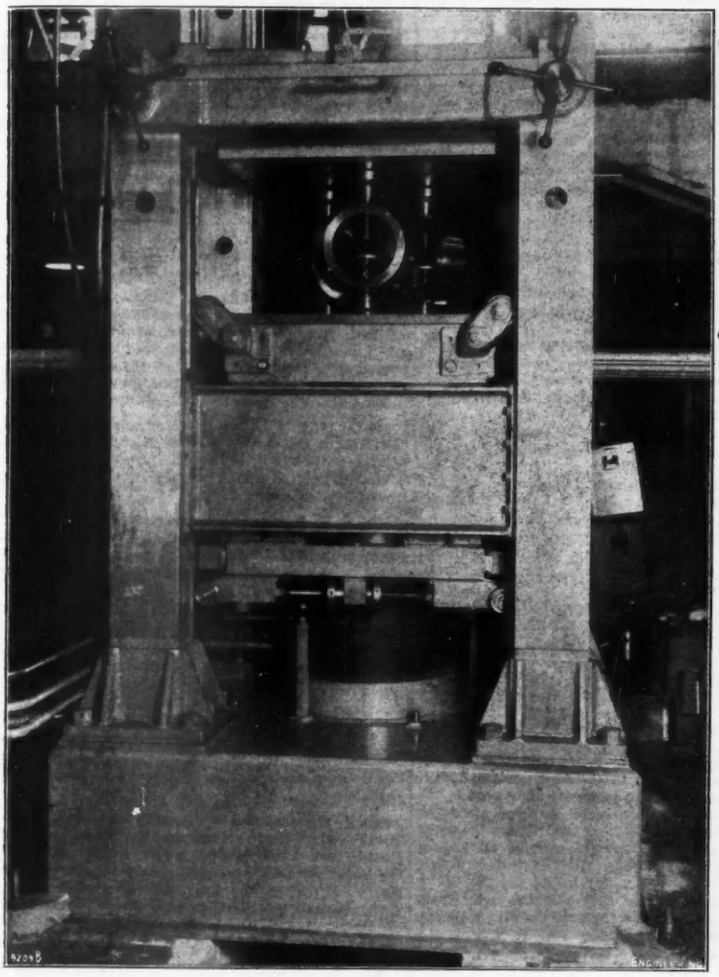

FIG. 4. PROVING RINGS IN COMPRESSION UNIT.

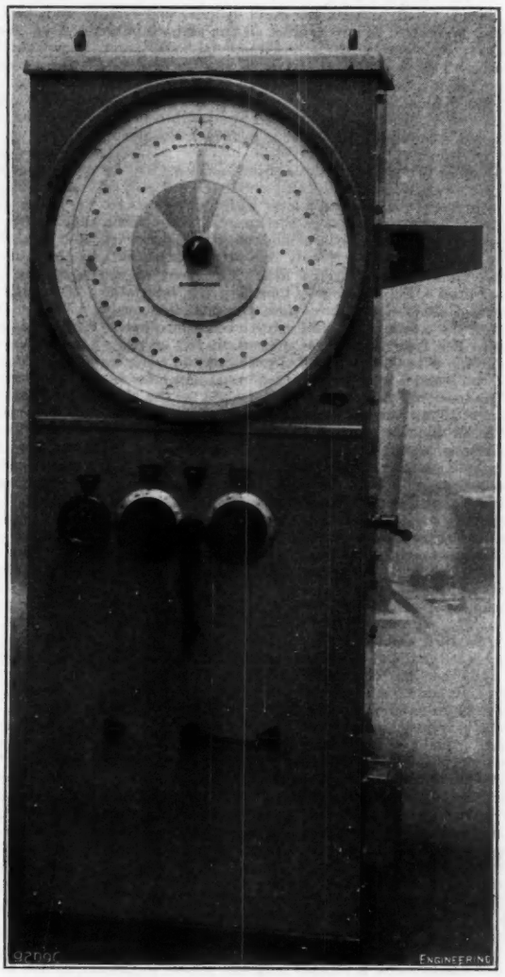

FIG. 5. LOAD-INDICATING AND CONTROL CABINET.

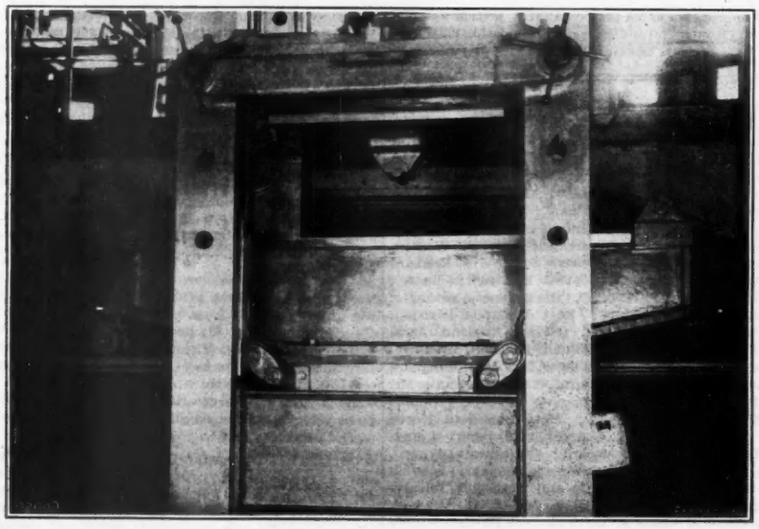

FIG. 6. BENDING-TEST BEAM IN POSITION.

balanced by cast-iron weights with wire ropes passing over pulleys at the tops of the columns. The platform is fabricated from light alloy, and is raised or lowered by hand. It is locked by moving a lever which inserts four plungers into holes in the columns. These holes are drilled at 12-in. intervals to allow the platform to be locked in any position over the length of the specimen.

The compression unit is used for transverse or bending tests, and a transportable beam is provided for this purpose, as shown in Fig. 6, and in Figs. 1 and 2, opposite. The beam is bolted to the lower platen, and is fitted with two bending dogs, each 8 in. wide, in the form of a roller in a mounting, which may be fixed anywhere along the upper surface of the beam, the maximum span being 7 ft. A presser foot (another roller in a mounting), is bolted to the centre of the upper platen. The beam is moved into position on rubber-tyred wheels: two "fixed" wheels at one end, and a detachable "tuglift" handle and wheels at the other end. Steel bridges are provided to span the gaps between the lower platen and the foundation pit, thus allowing the beam to be wheeled into position.

The hydraulic pump for feeding the cylinders is of the high-speed multiple-plunger type, delivering oil at high pressure; and it is enclosed in the oil tank adjacent to the foundation of the compression unit. The pump is driven by V-belts from a 5-h.p. motor, which is supplied with three-phase current at 400-440 volts and at 50 cycles. It is started and stopped by push-buttons, *a*, Fig. 2, on the front of the load-indicating and control cabinet. The lever *b*, at the bottom of the cabinet, is for changing over the oil delivery and indicating apparatus from the compression unit to the tension unit, and vice versa. It points to the unit which is connected, and a hydraulic interlock prevents the change being made while a load is being applied. The oil pump gives a maximum straining speed, under load, of 4 in. per minute; but to permit rapid movement of the rams for setting, with no load other than the weight of the components, a low-pressure large-delivery pump, operated by lever *c*, is also incorporated, and this moves the rams at a maximum speed of 18 in. per minute.

The load is measured by a small hydraulic ram, sliding in a cylinder which is connected to the oil pipe feeding the main ram; and it is indicated on a large

dial by a rotating pointer which is connected to the ram by a system of levers. The small ram and cylinder are mounted in the cabinet, and are connected to the oil pipe feeding one or the other of the main testing units, according to the position of the change-over lever. A liner is fitted between the small cylinder and ram, and it is rotated, to maintain an oil film and minimise friction, by a worm drive from a fractional-horse-power motor. This motor starts and stops with the main oil-pump motor, so that the friction of the small ram is always eliminated when tests are in progress. The load on the small ram is counterbalanced by a weighted lever, which is connected to the pointer by a rack-and-pinion mechanism.

In order to use the full circle of the indicating dial for a wide range of loads, and thus increase the accuracy of measurement at low loads, a lever with four alternative fulcra is interposed between the ram and the pointer. The dial is provided with a movable back plate with four sets of figures, but only one set is visible at a time, through holes in the dial. Movement of the handwheel *d*, Fig. 2, to one of four positions, brings the required set of figures into view, and, simultaneously causes the corresponding fulcrum to come into operation. The four load ranges are: 0 to 150 tons, by 0·5 ton; 0 to 75 tons, by 0·2 ton; 0 to 30 tons, by 0·1 ton; and 0 to 15 tons, by 0·05 ton. An inner set of graduations, 21 in. in diameter, is used for the 150-, 30- and 15-ton ranges; and an outer set of graduations, 23 in. in diameter, is used for the 75-ton range. The pointer is in the same plane as the graduations, to eliminate parallax. To assist the accurate reading of the maximum load, a dummy pointer, which can be re-set by hand, is mounted concentrically with the load-indicating pointer. Before a test is undertaken, the indicating pointer is set to zero, and the effect of the weight of the specimen eliminated, by adjusting a thumbscrew *e*. Overloading (*i.e.*, the pointer completing the full circle, whatever range is in use), is prevented by a mercury switch on the rack operating the pointer. This switch breaks the circuit of the main pump motor, and the circuit is automatically closed again as soon as the load is reduced and the pointer passes the trip position.

The other controls on the cabinet are used for applying, maintaining and reducing the load. A piston-type valve in the cabinet is controlled by a lever *f*, which has three positions: "load," "sustain load," and "unload." The rate at which each of these operations is performed is varied, as required, by one or other of three handwheels, *g*, *h* and *i*. Handwheels *g* and *h* are used for loading and unloading, respectively, and each is provided with a graduated dial to facilitate repeating a setting. With lever *f* in the appropriate position, for example, on "load," handwheel *g* is rotated until the desired rate of loading is obtained; and similarly with handwheel *h*. Each handwheel controls a needle valve, which is designed to give a constant flow of oil, at a given setting, regardless of change of pressure or variation in pump delivery. If it is required to sustain a given load, lever *f* is set to "sustain load," and the small handwheel *i*, is rotated until the pointer remains stationary. This handwheel controls another needle valve, which supplies oil to make up slight losses due to leakage. Any needle valve may be pre-set as required, and need not be adjusted when changing from loading to unloading.

ALMANACS AND CALENDARS.—Tear-off wall calendars with two months to each page have been received from Messrs. Ruston-Bucyrus Limited, Excavator Works, Lincoln; and Messrs. Automotive Products Company, Limited, Leamington Spa, and associated companies. We have received tear-off wall calendars with three months on each page from Messrs. C. A. Parsons and Company, Limited, Heaton Works, Newcastle-upon-Tyne 6; and Messrs. Wadkin Limited, Green Lane Works, Leicester. The Eyre Smelting Company, Limited, Tandem Works, Merton Abbey, Lonon, S.W.19, have sent us their monthly tear-off wall calendar, which has on the reverse side a chart showing the sizes and weights of the chill-cast phosphor-bronze and gun-metal rods supplied by them.

BRITISH ASSOCIATION.—The next meeting of the British Association will be held in Brighton from September 8 to 15. The President will be Sir Henry Tizard, K.C.B., F.R.S., the general treasurer, Mr. M. G. Bennett, and the general secretaries, Dr. Edward Hindle, F.R.S., and Sir Richard Southwell, F.R.S. The Presidents of the various Sections are to include Sir Lawrence Bragg, O.B.E., F.R.S. (Physics and Mathematics); Professor John Read, F.R.S. (Chemistry); Dr. A. E. Trueman, F.R.S. (Geology); Professor Sir Hubert D. Henderson (Economics); Wing-Comdr. T. R. Cave-Browne-Cave, C.B.E. (Engineering); Mr. W. O. Lester Smith, C.B.E. (Education); and Dr. G. Scott Robertson (Agriculture). Further particulars may be obtained on application to the offices of the Association, Burlington House, Piccadilly, London, W.1.

BOOKS RECEIVED.

Monographs on Electrical Engineering. Volume VI. *Electricity Meters and Meter Testing.* By G. W. STUBBINGS. Second edition, revised. Chapman and Hall, Limited, 37, Essex-street, Strand, London, W.C.2. [Price 16s. net.]

Technical Aerodynamics. By PROFESSOR KARL D. WOOD. Second edition. McGraw-Hill Book Company, Incorporated, 330, West 42nd-street, New York 18, U.S.A. [Price 5·50 dols.] McGraw-Hill Publishing Company, Limited, Aldwych House, Aldwych, London, W.C.2. [Price 33s.]

"Mechanical World" Monographs. No. 41. *Planning Factory Maintenance.* By F. D. DENNER. Emmott and Company, Limited, 31, King-street West, Manchester 3. [Price 1s. 6d. net.]

Locomotives of the L.M.S. Official Illustrated List of All L.M.S. Locomotives Specially Arranged for Engine Spotters. [Price 2s. 6d. net.] Set of six postcards of *Modern L.M.S. Locomotives*, in colour. [Price 1s. 6d. the set.] Advertising and Publicity Department, London Midland and Scottish Railway Company, Euston House, London, N.W.1.

Locomotives Old and New. Some of the Engines Built by the L.M.S. and its Constituent Companies, 1829 to 1947. Advertising and Publicity Department, London Midland and Scottish Railway Company, Euston House, London, N.W.1. [Price 2s. 6d. net.]

The Elements of Fuel Technology. By DR. GODFREY W. HIMUS. Leonard Hill Limited, 17, Stratford-place, London, N.W.1. [Price 42s.]

The Oakwood Library of Railway History. No. 5. *The Cheshire Lines Railway.* By R. PRYS GRIFFITHS. The Oakwood Press, "Tanglewood," South Godstone, Surrey. [Price 6s. 6d. net (paper); 8s. 6d. net (cloth).].

The Euston and Crewe Companion. By D. S. BARRIE. The Oakwood Press, "Tanglewood," South Godstone, Surrey. [Price 4s. 6d. net.]

Elementary Engineering Thermodynamics. By PROFESSOR VINCENT W. YOUNG and GILBERT A. YOUNG. Third edition. McGraw-Hill Book Company, Incorporated, 330, West 42nd-street, New York 18, U.S.A. [Price 3 dols.] McGraw-Hill Publishing Company, Limited, Aldwych House, Aldwych, London, W.C.2. [Price 18s.]

Cement and Concrete Association. Bibliography of Cement and Concrete. List of Books and Papers in London Libraries Arranged in Chronological Order. Offices of the Association, 52, Grosvenor-gardens, Westminster, London, S.W.1. [Free to approved applicants.]

Ministry of Transport. Railways Division. Railway Accidents. Report on the Collision which Occurred on the 9th August, 1947, near Doncaster, on the London and North Eastern Railway. H.M. Stationery Office, Kingsway, London, W.C.2. [Price 6d. net.]

Department of Scientific and Industrial Research. Road Research. Road Note No. 3. *Effect of Batching Errors on the Uniformity of Concrete.* By DR. A. R. COLLINS. H.M. Stationery Office, Kingsway, London, W.C.2. [Price 4d. net.]

The Short Road to Industrial Co-operation. A Report of the Annual Conference Held by the British Association for Commercial and Industrial Education at Ashridge, Berkhamsted, 3rd to 6th October, 1947. British Association for Commercial and Industrial Education (BACIE), 107, Baker-street, London, W.1. [Price 5s.]

BRITISH ELECTRICITY AUTHORITY APPOINTMENTS.—The following appointments of divisional controllers have been announced by the British Electricity Authority: London Division, Mr. J. N. Waite, manager, South East England and East England Areas, Central Electricity Board; South Eastern Division, Mr. W. C. Parker, borough electrical engineer, Fulham; Southern Division, Mr. R. H. Coates, engineer and manager, Portsmouth Corporation Electricity Department; South Western Division, Mr. J. H. Legge, manager, South West England and South Wales Areas, Central Electricity Board; Eastern Division, Mr. W. N. C. Clinch, general manager, Northmet Power Company; East Midlands Division, Mr. W. S. Burge, manager, Central England Area, Central Electricity Board; Midlands Division, Mr. F. W. Lawton, chief engineer and manager, City of Birmingham Electricity Department; South Wales Division, Mr. H. V. Pugh, deputy chief engineer, Manchester Corporation Electricity Department; Merseyside and North Wales Division, Mr. A. R. Cooper, chief operation engineer, Central Electricity Board; Yorkshire Division, Mr. G. A. Vowles, chief engineer and manager, Ipswich Corporation Electricity Supply and Transport Departments; North Eastern Division, Mr. J. C. Mitchell, chief mechanical engineer, North Eastern Electric Supply Company; North Western Division, Mr. C. T. S. Arnett, manager, North West England and North Wales Areas, Central Electricity Board; South East Scotland Division, Mr. J. F. Field, engineer and manager, Edinburgh Corporation Electricity Department; and South West Scotland Division, Mr. E. J. Edgar, manager, Central and South of Scotland Areas, Central Electricity Board.

PERSONAL.

SIR JOHN B. GREAVES, C.B.E., has been elected a director of Ruston and Hornsby, Limited, Lincoln.

MR. I. A. MARRIOTT, who joined the new board of W. G. Bagnall Limited, Stafford, when it was acquired by Heenan and Froude, Limited, last year, has been appointed managing director. He is also acting as the representative of the Brush Electrical Engineering Company, Limited, on the Internal-Combustion Group of the Locomotive Manufacturers Association.

MR. S. A. LANE, formerly managing director of Tarran Industries, Limited, has joined the board of the Brush Electrical Engineering Company, Limited, and has been appointed general manager.

MR. C. T. GARDNER, A.M.I.C.E., M.Inst.T., who has held the appointment of Deputy Director of Canals, Ministry of Transport, since 1942, is relinquishing that appointment in consequence of changes occasioned by the nationalisation of inland waterways.

CAPTAIN B. R. WILLETT, C.B.E., D.S.C., general manager of Marconi's Wireless Telegraph Company, Limited, Marconi House, Chelmsford, Essex, has been given an appointment, the object of which will be to intensify the firm's export trade. He will be succeeded as general manager by MR. F. N. SUTHERLAND, B.A., A.M.I.E.E.

MR. J. H. B. FORSTER has been appointed chairman and MR. B. CHETWYND TALBOT deputy chairman and managing director of the South Durham Steel and Iron Company, Limited, and of the Cargo Fleet Iron Company, Limited, Middlesbrough.

MR. J. M. SURRALL, general commercial manager of the Simplex Electric Company, Limited, Oldbury, Birmingham, has been appointed a director of the firm, which is a subsidiary company of Tube Investments Limited, The Adelphi, London, W.C.2.

MR. DONALD H. BARRACLOUGH has left England for Australia, where he is to join the staff of the Sydney Metropolitan Water, Sewage and Drainage Board as inspector of sewage-treatment works.

Following the death of MR. HARRY PALMER, MR. J. R. TOMLINSON has been appointed agent in charge of the Cleveland ironstone mines of Dorman, Long and Company, Limited, Middlesbrough. MR. W. I. E. HICKMAN has been appointed agent in charge of the company's limestone quarries, the Burley ironstone quarry and the Eston mine.

MR. S. E. CLARK has been appointed secretary to the Docks and Inland Waterways Executive under the British Transport Commission. MR. W. L. IVES, LL.B., has been appointed assistant secretary (waterways) and MR. W. J. NICHOLLS, accountant. The headquarters of the Docks and Inland Waterways Executive are now at 22, Dorset-square, Marylebone, London, N.W.1. (Telephone: PADdington 1831.)

MR. H. BUTTERWORTH, Assoc.M.C.T., A.M.I.E.E., sales manage of the motor and industrial control departments of the Metropolitan-Vickers Electrical Company, Limited, has resigned to take up an executive appointment with Edison Swan Electric Company, Limited He has been succeeded as sales manager, motor department, by MR. H. BOYD BROWN, B.Sc. (Eng.), and as sales manager, industrial control department, by MR. C. H. DE NORDWALL, M.I.E.E. MR. F. R. MASON, B.Sc. Tech., A.M.I.Mech.E., is to succeed Mr. Brown as principal representative at Trafford Park, of the Metropolitan-Vickers Electrical Export Company, Limited.

MR. G. R. JACKSON has agreed to act as representative of the Institution of Heating and Ventilating Engineers on the British Standards Institution Committee engaged on the standardisation of flue pipes and fittings. Mr. Jackson succeeds MR. A. B. POTTERTON, who has now retired from this work.

An agreement has been concluded between MESSRS. VICKERS-ARMSTRONGS LIMITED, Vickers House, Broadway, London, S.W.1, and MESSRS. SULZER BROTHERS (LONDON), LIMITED, 31, Bedford-square, London, W.C.1, under which Messrs. Vickers-Armstrongs will manufacture Sulzer engines for locomotives and other rail-traction services at their Barrow-in-Furness Works. All questions of sales and the co-ordination of design of the complete vehicles will be handled by Sulzer Brothers (London), Limited.

COLLIERY ENGINEERING LIMITED, and HEAD, WRIGHTSON AND COMPANY, LIMITED, have entered into an agreement whereby the latter firm have been granted the rights to design, manufacture and sell coal-preparation plant under the designs, patents and licences owned by Colliery Engineering, Limited. These include the Barvoys coal-cleaning processes under patents of Staatsmijnen in Limburg (Dutch State Mines).

The Birmingham area office of the Board of Trade TIMBER CONTROL is designated No. 10 and not No. 13, as erroneously stated on page 34, *ante*.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scottish Steel.—Sir Stafford Cripps's announcement of a cut of one-fifth in the allocation of steel for the shipbuilding industry, was received in Scotland, and particularly in Clydeside, with considerable consternation. First estimates suggest that 12,000 shipyard workmen in the West of Scotland may be affected. Shipbuilders have always been the mainstay of the Scottish steelmaking industry. They constitute its largest single consumers taking as much as 28 per cent. of the total output from the rolling mills. Leaders of the shipbuilding industry have been making strong representations to have the decision rescinded, and while appreciating the circumstances surrounding the decision (so far as these have been disclosed or can be guessed at), are hoping that even yet its reversal may be achieved, as was the case when a cut was suggested towards the end of last year. It appears a more forlorn hope on this occasion, however, and Scottish steelmakers are expecting that the tonnage "saved" will be transferred to other areas, either for fabrication or for shipment overseas. Speaking generally, the policy allowing steel to leave this country for manufacture into ships and other articles which could well be made at home is deplored by practically all groups of opinion. Since the New Year holidays, steelmakers locally have been restoring production to near the high level ruling in December, and with the likelihood of assurance of larger tonnages of pig-iron following the lighting of the new blast-furnace at Clyde Iron Works, Glasgow, they have been partly relieved of one of their anxieties in fulfilling their obligation to provide a full share of the national steel target of 14,000,000 ingot tons.

Scottish Coal.—In the first week of 1948, Scottish deep-mine production amounted, provisionally, to 467,300 tons, which was some 4 per cent. under the average weekly output of about 490,000 tons during November and December, the two best months in 1947. In the second week, sporadic stoppages, lasting a few days mostly, occurred at a few pits in Lanarkshire. These cost over 2,000 tons in output, but the loss was largely made up by improved performances at unaffected collieries. Good weather has kept down consumption, and supplies generally have been adequate. Receipts of industrial and steam coal for general purposes have been satisfactory. Coke-oven supplies have been maintained at a high level to ensure maximum coke production, local supplies of which have had to be further supplemented by consignments from the South to meet higher blast-furnace throughputs. Exports have been moving steadily. Details of a new town in East Fife, to be known as Glenrothes, and which will be the focal point of extensive coal developments, have been given in a Draft Designation Order. The present annual output of the East Fife coalfield averages 2,000,000 tons, and it is intended to increase that figure within the next 20 years to 6,500,000 tons, offsetting to some extent the general decline of the Lanarkshire coalfield.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

Welsh Coal Trade.—Mr. Brynmor Davies, a Cardiff consulting engineer, who was elected President of the South Wales Institute of Engineers during the past week, was chairman of the South Wales Coalowners' Association in 1937. He contrasted British and American mining methods, and giving the results of his investigations in the United States, said that it was unlikely that the longwall method of working, used so extensively in South Wales, would be superseded to any great extent by American methods. At the same time, the advantages of the American system should be fully explored, since it could be adopted in many Welsh mines. The output per man per annum was 1,350 tons in America, against 260 tons in Britain and about 200 tons in South Wales. The cost of production in 1946 was 15*s.* 6*d.* per ton in America, 35*s.* 10*d.* per ton in Britain, and 39*s.* 5*d.* per ton in South Wales. The removal of the threat of a stoppage in the coalfield by the winding enginemen, who agreed to submit their case to a tribunal, was accompanied by complaints that at two collieries in the coalfield their members had been intimidated by members of the National Union of Miners. The undermanagers also threatened to strike as a result of dissatisfaction at their rates of pay. The supply position has been extremely difficult on the Welsh steam-coal market during the week. This was very largely due to the slowing down of operations at the mines after the Christmas holidays, but it was hoped that it would soon be improved. In spite of this, however, further export business was arranged. This was in respect of about 4,000 tons destined for Lisbon, this being the third cargo to be sent to this destination since the recent resumption of shipments. The requirements of the inland section however, were still very heavy and it was difficult to enter into business for delivery until late in February. The high-priority home consumers were accounting for the bulk of current outputs.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Iron and Steel.—Steel production continues to increase. A leading firm of steelmakers has just achieved a new high record of ingot production in one week at its plant. Schemes of re-organisation are being pursued as speedily as the scarcity of machine tools will permit. The Minister of Supply has acceded to a suggestion that, for furnace and other repairs of a relatively small nature, no permit need be asked for, but permits must be obtained for bigger jobs. Delay in securing permits has been holding up steel-furnace repairs urgently needed if steel targets are to be achieved. Messrs. Hadfields Limited, are making headway with the mechanisation and reorganisation of their steel foundry. It has been possible already to achieve the 10 per cent. increased production asked for, and now a new target, representing a 15 per cent. increase, has been set. Replacement of the steel-melting plants at Hadfields will permit an increase in steel production of 10,000 tons a year. In complying with requests for quicker delivery of colliery equipment, Hadfields are now turning out colliery wheels at a rate of 5,000 a week and hope to be able to increase this to 8,000 a week when the casting shop is fully mechanised at the end of February. Messrs. Davy and United Engineering have five major contracts for the supply of plant and machinery for the home trade, as well as contracts for machinery for New South Wales, Portugal, Holland and Turkey. At the works of Messrs. Thos. Firth and John Brown, and of Messrs. Davy and United Engineering, heavy machine tools, acquired from Germany under reparations, are now being installed.

South Yorkshire Coal Trade.—The increased production of coal is permitting the resumption of export trade through the Humber ports. A cargo of South Yorkshire coal has left Hull for New Zealand, and a further cargo is to be shipped to New Zealand before the end of February, making 20,000 tons in six weeks. Industrial steams are in continued good request, and deliveries are on a scale which has made it unnecessary to draw upon reserves; some firms have been able to make additions to stocks. Sufficient coal is being delivered for the use of power stations, but more gas coal could be dealt with. Coke-oven gas is more plentiful as a result of increased allocations of coking coal.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

General Situation.—Buyers of iron and steel are still anxious to place orders for delivery over any period that conditions permit, but the total tonnage output, although at a very high level, is not sufficient to enable producers to handle satisfactorily the extensive contracts they have in hand. The demand for larger supplies of most descriptions of material continues both for home purposes and for the export markets. Some improvement in supplies of pig iron and scrap for the foundries and steel plants can be reported, but much larger quantities of these commodities are still urgently needed. A promise to speed up the issue of authorities to proceed with deferred maintenance and repairs of steel furnaces is a welcome announcement. On the other hand, the decision to curtail steel allocations to the shipbuilding industry has occasioned grave concern. Shipbuilders declare that this is bound to slow down production.

Foundry and Basic Iron.—Foundry pig iron is in rather better supply than of late, but consumers still require much larger quantities than they are receiving. The make of Cleveland foundry pig has almost ceased and deliveries from other producing areas still fall short of the demand. The bulk of the iron being used in North-East Coast foundries still comes from Midland blast-furnaces. The whole of the basic-iron output is conveyed directly from the blast to the steel furnaces.

Hematite, Low-Phosphorus and Refined Iron.—Regular users of East Coast hematite are able to obtain parcels sufficient to meet their requirements, but are still unable to obtain iron for the restocking of the empty storage yards. The outputs of low- and medium-phosphorus grades of iron are going promptly into use and larger supplies would be acceptable. The output of the refined-iron manufacturers finds a ready sale.

Manufactured Iron and Steel.—Semi-finished and finished-iron firms have commitments that will keep them actively engaged for a considerable time and steel producers' delivery obligations are still vastly greater than they can meet. Makers of steel semies cannot keep pace with the demand for their products. Re-rollers are in urgent need of billets, blooms and sheet bars, and readily accept any usable defective home or foreign products. The large quantities of ingots reaching the heavy rolling mills, however, about cover present requirements. There is no reduction in the heavy demand for finished steel. Black and galvanised sheets, and all classes of railway material and colliery equipment, are still in heavy demand.

NOTICES OF MEETINGS.

It is requested that particulars for insertion in this column shall reach the Editor not later than Tuesday morning in the week preceding the date of the meeting.

INSTITUTION OF ELECTRICAL ENGINEERS.—Monday, January 26, 5.30 p.m., Victoria-embankment, W.C.2. Discussion on "The British Patent System," to be opened by Mr. C. S. Parsons. *North-Eastern Centre:* Monday, January 26, 6.15 p.m., Neville Hall, Newcastle-upon-Tyne. "Protective Finishing of Electrical Equipment," by Messrs. F. Widnall and R. Newbound. *East Midland Centre:* Tuesday, January 27, 6.30 p.m., Loughborough College, Loughborough. "Standardisation of Switchgear," by Messrs. D. E. Lambert and J. Christie. *Scottish Centre:* Tuesday, January 27, 6.30 p.m., Royal Technical College, Glasgow. "Speech Communication Under Conditions of Deafness or Loud Noise," by Dr. W. G. Radley. *Measurements Section:* Friday, January 30, 5.30 p.m., Victoria-embankment, W.C.2. Discussion on "Instrument Design."

JUNIOR INSTITUTION OF ENGINEERS.—*Sheffield Section:* Monday, January 26, 7.30 p.m., 198, West-street, Sheffield. "Seamless Steel Tubes," by Mr. T. P. Nicholls. *Institution:* Friday, January 30, 6.30 p.m., 39, Victoria-street, S.W.1. "Modern Plastics," by Dr. C. L. Child. *North-Western Section:* Saturday, January 31, 2.30 p.m., 16, St. Mary's Parsonage, Manchester. "Modern Foundry Practice," by Mr. W. Rawlinson.

INSTITUTION OF CIVIL ENGINEERS.—Tuesday, January 27, 5.30 p.m., Great George-street, S.W.1. "Design, Installation and Maintenance of Long Welded Rails," by Messrs. C. E. Dunton and Keith Brinsmead. *Newcastle-upon-Tyne Association:* Tuesday, January 27, 6.15 p.m., Mining Institute, Westgate-road, Newcastle-upon-Tyne. "Coast Erosion," by Mr. J. Duvivier.

INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND.—Tuesday, January 27, 6.30 p.m., 39, Elmbank-crescent, Glasgow. "The Exhaust-Pulse Pressure-Charged Two-Stroke Diesel Engine, Marine and Locomotive," by Mr. H. D. Carter.

SOCIETY OF INSTRUMENT TECHNOLOGY.—Tuesday, January 27, 7 p.m., Manson House, Portland-place W.1. "Electronic Methods of Measurement in Engineering," by Dr. G. E. Bennett, Dr. J. R. Richards and Mr. E. C. Voss.

INSTITUTION OF HEATING AND VENTILATING ENGINEERS.—*Scottish Branch:* Tuesday, January 27, 7.30 p.m., 39, Elmbank-crescent, Glasgow. "Combustion," by Mr. P. J. Hill.

ROYAL SOCIETY OF ARTS.—Wednesday, January 28, 2.30 p.m., John Adam-street, W.C.2. "The Making of Precision Instruments," by Mr. A. J. Philpot.

INSTITUTE OF WELDING.—Wednesday, January 28, 6 p.m., Institution of Civil Engineers, Great George-street, S.W.1. "Welded Components in House Construction and Welded Bunkers in Power Houses," by Mr. J. Corston Mackain.

ROYAL MICROSCOPICAL SOCIETY.—Wednesday, January 28, 6 p.m., B.M.A. House, Tavistock-square, W.C.1. "Microscopy of Coal," by Dr. C. Seyler.

INSTITUTION OF PRODUCTION ENGINEERS.—*Manchester Section:* Wednesday, January 28, 7.15 p.m., Mechanics Institute, Crewe. "Mechanical Mishaps," by Mr. G. E. Windeler.

ROYAL SOCIETY.—Thursday, January 29, 4.30 p.m., Burlington House, Piccadilly, W.1. "Radio-Frequency Radiation from the Sun," by Messrs. M. Ryle and D. D. Vonberg. "Solar Radiation in the Radio Spectrum: Radiation from the Quiet Sun," by Mr. D. F. Martyn.

INSTITUTION OF MECHANICAL ENGINEERS.—*North-Western Branch* and AUTOMOBILE DIVISION (*Manchester Centre*): Thursday, January 29, 6.45 p.m., Engineers' Club, Manchester. Automobile Division Chairman's Address, by Captain G. T. Smith-Clarke. *Southern Branch:* Thursday, January 29, 7 p.m., University College, Southampton. Thomas Lowe Gray Lecture, by Mr. T. A. Crowe. *Institution:* Friday, January 30, 5.30 p.m., Storey's-gate, S.W.1. "Technique of Radio Valve Manufacture," by Messrs. J. W. Davies, H. W. B. Gardiner and W. H. C. Gomm. AUTOMOBILE DIVISION: *Birmingham Centre:* Tuesday, January 27, 6.30 p.m., James Watt Institute, Birmingham. Automobile Division Chairman's Address.

CHEMICAL SOCIETY.—Thursday, January 29, 7 p.m., Engineers' Club, Manchester. "Nitration by Mixtures of Nitric and Sulphuric Acids," by Dr. G. M. Bennett, F.R.S. Friday, January 30, 4.30 p.m., The University, Edgbaston, Birmingham. "Infra-Red Spectroscopy Applied to Chemical Problems," by Dr. G. B. B. M. Sutherland.

MANCHESTER STATISTICAL SOCIETY.—*Industrial Group:* Friday, January 30, 6.45 p.m., 16, St. Mary's Parsonage, Manchester. "Statistical Methods in Industrial Chemistry," by Mr. K. A. Brownlee.

150-TON STRUCTURE-TESTING MACHINE.

MESSRS. W. AND T. AVERY, LIMITED, BIRMINGHAM.

(*For Description, see Page 79.*)

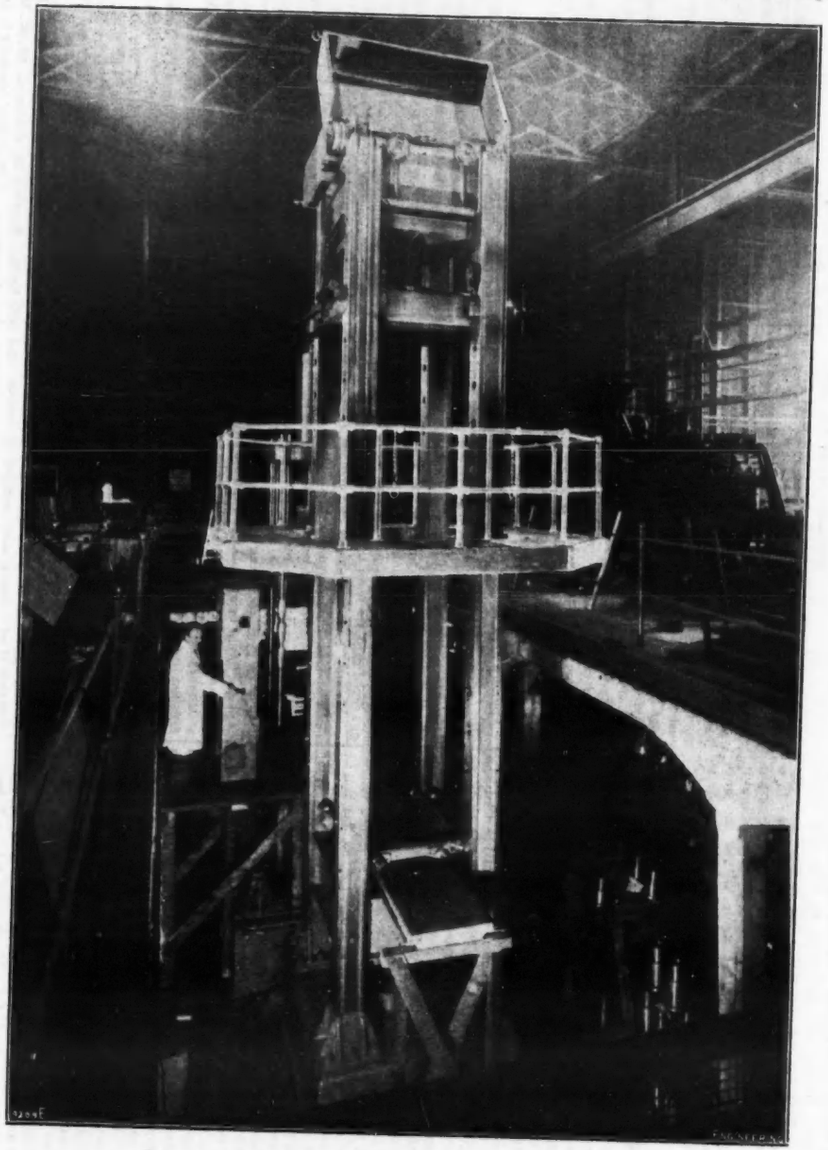

FIG. 7. MACHINE ERECTED IN MANUFACTURER'S WORKS.

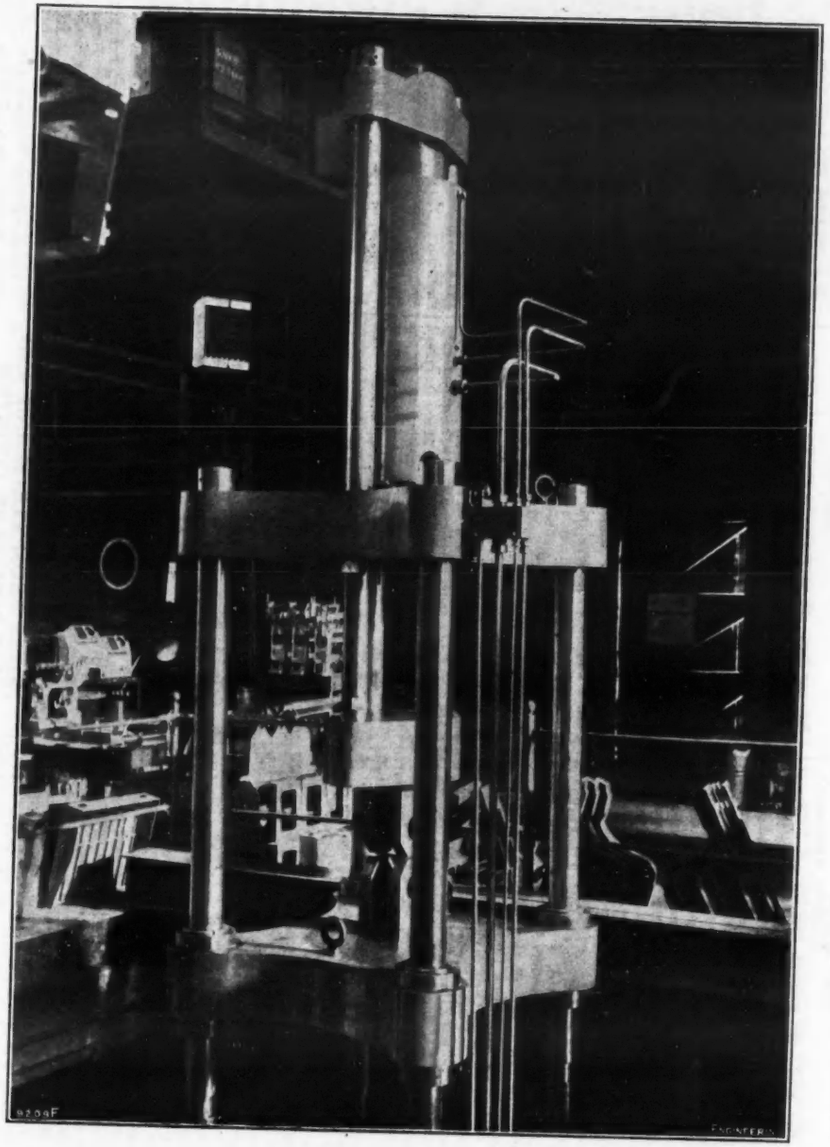

FIG. 8. TENSILE-TEST UNIT.

ENGINEERING.

35 & 36, BEDFORD STREET, STRAND, LONDON, W.C.2.

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Telephone Numbers:
TEMPLE BAR 3663 and 3664.

All editorial correspondence should be addressed to the Editor and all other correspondence to the Manager.

Accounts are payable to "ENGINEERING," Ltd. Cheques should be crossed "The National Provincial Bank, Limited, Charing Cross Branch." Post Office Orders should be made payable at Bedford Street, Strand, W.C.2.

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ENGINEERING

FRIDAY, JANUARY 23, 1948.

VOL. 165. No. 4278.

ROLLING BEARINGS AND EUROPEAN RECOVERY.

LONG before the outbreak of hostilities in 1939, it was recognised in military circles that the successful prosecution of any future European war must involve attention to a number of economic targets which, in previous wars, had been of much less crucial importance. Ever since warfare had developed from the stage of a few pitched battles between relatively small and compact forces, following long periods of strategic manœuvres and insignificant encounters of scouting parties, into large-scale operations in which the destruction of transport facilities was an indispensable prelude to the major combats, it was becoming increasingly evident that the reduction of an opponent's manufacturing potential was tending to become a prime consideration of war staffs; but even the experience of the first world war hardly indicated how essential this policy was to become in the second world war. That realisation, however, and the need to build up an adequate production organisation as a basic requirement of any conflict on a national scale, was certainly well in the minds of the British military authorities years in advance of 1939, even though the means to deny to an enemy the benefit of his own industries were then far from adequate to the task that was so clearly foreseen.

Prominent among the targets that these considerations indicated were, in addition to those of transport, steelworks, munition works, and synthetic and other oil plants, the factories devoted to the production of ball and roller bearings. True as it still is that an army marches on its stomach, it is no less true to say that it rides on the products of the ball-bearing industry; without which, mechanical transport on any large scale, whether by land or air, would be virtually impracticable. This dependence is the more fundamental if there is any likelihood, as there was in Germany, that war on an international scale might lead to a shortage of lubricants; and the great extension, in the years between the wars, of small power drives, either by electric motors or by internal-combustion engines—especially the former—exposed to a similar risk of interruption practically every industry in which mechanisation had made appreciable headway. The German industrial direction, working in close association with the military High Command, did not fail to observe this feature of modern industry; and there can be little doubt, looking back, that the expansion of ball and roller bearing manufacture, under the Hitler regime, was due at least as much to this impulse as to the desire to obtain an increasing hold on foreign markets. Sweden, the largest European exporter of such bearings, was inspired solely by economic motives; but those of Germany were largely military, any economic advantage, though welcome as such, being secondary.

The vital importance in peace-time also of the "rolling bearing"—to use the generic term adopted by Mr. R. K. Allan as the title of his authoritative book, which we reviewed on page 531 of our 164th volume (1947)—is emphasised in the instalment of the "Engineering Outlook" series of articles which appears in this issue of ENGINEERING; but, since that article is concerned primarily with the British engineering industry, it hardly indicates, except by inference, how seriously the whole of Europe, and much of the machine-using world outside Europe, is suffering from a similar shortage. In fact, however, in spite of war-time expansions of manufacturing capacity, there is a very general lack of bearings of this type, and there can be no doubt that the deficiency is materially retarding economic recovery, both in the reconditioning of existing plant, prematurely aged by hard driving and insufficient maintenance during the war years, and in the provision of new equipment to replace that destroyed, or damaged beyond practicable repair.

The incidence of this problem is so widespread, and its solution so urgently necessary, that it has now been taken in hand at the highest level, namely, by the United Nations organisation itself. Towards the end of 1947, the matter was discussed by the Economic Commission for Europe, and the Industry and Materials Committee of the Economic Commission decided to set up a "working party" to examine it in full detail. This Working Party on Ball Bearings met for the first time, in Geneva, on January 9, the meeting being attended by representatives from Czechoslovakia, France, Italy, Sweden, Switzerland, the United Kingdom and the United States. With commendable promptitude, the London Information Centre of the United Nations has issued already a précis of the Committee's terms of reference and the general scope of the matters under discussion, from which it appears (though the report does not state specifically whether the representative "experts" were principally economists or engineers) that a considerable amount of work has been done to define the scope of the survey, the resources available, and the nature and significance of the principal bottlenecks. From the incidental statement that invitations to participate have been sent to 21 nations, in addition to those mentioned above, it may be inferred that the full range of the intended investigation is appreciably wider than that covered by the preliminary report; though it is evident, too, that a firm basis for the inquiry has been established at the outset.

When the Industry and Materials Committee considered the problem in November last, they reached the conclusion that *ad hoc* working parties, dealing with specific items in the field of "components and parts" of industrial equipment, could do more useful work than could a general body covering the whole field. The present working party, therefore, are concerned particularly with ball and roller bearings (including needle bearings) and their main objective is to ascertain how best to bring the existing unused production facilities into service again and thus to increase supplies. All three types of bearings are in heavy demand for use in connection with electric power, transport, mining, and many other industries; but, while some manufacturers are finding themselves obliged to refuse new orders, a large part of the existing plant in Europe for producing such bearings is idle. As previously mentioned, Sweden and Germany, in that order, were the leading European exporters of ball and roller bearings before the war; but, it is stated, in both countries the present trade in bearings is now far below the pre-war levels. The German pre-war output was nearly double that of Sweden, though by far the greater part of it was absorbed within the country. Production in Sweden at the present time is hampered by a shortage

of labour; this, apparently, is the main restrictive factor, the supply of materials and the amount of available plant being fully adequate to provide for present needs and for an appreciable increase of output, up to twice the current figure. Italian labour, of which there is a surplus, is being taken into the Swedish industry to some extent to alleviate the position.

Probably the biggest reserve of unused ball-bearing machinery at the present time is in Germany, though the mere existence of the plant is no guarantee that it is in usable condition; the B.I.O.S. report (No. 346) on "The German Ball and Roller Bearing Industry," mentioned that, in some of the underground factories brought into service during the general dispersal of the industry as Allied bombing attacks increased in severity and improved in accuracy, deficient ventilation and, after the war, lack of maintenance, had led to extensive deterioration of the equipment and of the finished bearings in stock. During the war, German output of bearings was increased greatly, as was to be expected, though it is somewhat unexpected to learn, on the authority of the Economic Commission for Europe, that "at the end of the year of bombing [1943-4] the German industry had a greater stock of machine tools and capacity than when the bombing began." In spite of this increase, however, the output had fallen, partly because of the lower efficiency of production which followed dispersal, and partly because the dispersal was still incomplete at the conclusion of hostilities; the B.I.O.S. report states that, in some of the dispersed factories, the machines had not been unpacked from their crates. Even so, however, the total production was considerably above the pre-war level; in 1943, it was rather more than 115 millions and, in 1944, over 104 millions, exclusive of the ball-and-link joints which were widely used in the control gear of aircraft, etc., of which nearly 3½ millions were manufactured in the two-year period. Most of this productive capacity was situated in what is now the United States zone of occupation.

At the Potsdam Conference, the ball and roller bearing industries were classed as "war potential" and, like shipbuilding, aircraft construction, and other more obvious sources of munitions of war, were condemned to be expunged. It was realised, however, that an immediate and total cessation of production was impracticable, and the Level of Industry Plan laid down that "production will be permitted only until sufficient imports will be possible and can be paid for." Meanwhile, exports of bearings from Germany have ceased, and the plants have been listed as available as reparations, to be dismantled and removed in due course, though their eventual destinations have not been announced yet. So far as we are aware, none of the plant in the British and American zones has been removed yet, except for some in those parts of the American zone (for example, at the factory of the Vereinigte Kugellager Fabriken A.G., at Bad Cannstatt) which were previously in French occupation. There is still a very large amount of unused productive capacity in Germany, therefore, some of which could be brought into service to relieve the present shortage if a sufficiency of materials and power could be assured. There is, of course, no lack of labour to operate the German plants; though it may be that much of the machinery may have to be accommodated in new or converted buildings, since most of the factories, above and below ground, have been destroyed.

The general conclusions of the working party, so far as their investigations have gone, are that "there exists considerable idle capacity for the production of bearings in Europe" and that "the chief centres of unused capacity are Germany, Sweden, and probably Austria and Italy." It may be remarked that the availability of the Austrian capacity, chiefly concentrated at Linz after the main plant at Steyr was almost entirely destroyed by bombing in 1944, seems to be rather doubtful; but the principal Italian factories, all of which were at Turin, might well make a useful contribution towards this essential prerequisite of economic recovery, pending the expansion of British capacity which is reported to be planned, and a return to normal production and exports in Sweden.

THE WORK OF THE ATOMIC ENERGY COMMISSION.

As expressed by Mr. David E. Lilienthal, chairman of the United States Atomic Energy Commission, the explosion of the Hiroshima bomb "was followed by perhaps the greatest verbal detonation in history." In view of the secrecy which had marked the preparations for that event, and its complete unexpectedness, the emotion it generated is not a matter for surprise, but that denouement took place on August 6, 1945, and the months that have elapsed since that time should have allowed the question of the application of atomic energy to be viewed on broader and less susceptive lines. It has been suggested that the development of methods for the release and utilisation of atomic energy did not constitute a greater revolution in the history of mankind than did the discovery of means for the artificial production of fire, and that the impact of the later event on the everyday life of the individual is likely to be no more catastrophic than was the former. Speculation about the reactions of cave-men to the phenomenon of fire are not likely to lead to demonstrable conclusions, but as atomic energy, like fire, will, for good or ill, now affect life in many of its aspects, it is well that some possibilities broader than those of mere destruction should occupy public attention.

From the point of view of the scientific worker, and those who are concerned with the application of the results of physical research, it is unfortunate that this revolutionary development should still be thought of mainly in terms of its application to the political problems of a divided world—problems which have no relation of any kind to scientific advance. It is true that considerable publicity, of a highly optimistic character, has been given to the subject of the application of atomic energy in the production of mechanical power, but this has not prevented the whole matter from being still dominated by the question of bombs. Practically nothing of a specific nature has yet been published about developments promising practical results in the production of mechanical power. It is known that research is being carried on in this country; and in the United States, Mr. Lilienthal has said "some day the energy released by the splitting of the atoms of uranium and plutonium will provide a new source of electricity and heat." Mr. W. W. Waymack, also a member of the Commission, has stated that "it may well find a good many uses in industry as heat for power and processing and in transport as electricity."

As governmental bodies in the United States are less secretive about their proceedings than their opposite numbers in this country, it may be taken that, as nothing definite has been announced, work on power production has not as yet pointed to practical ends. The Atomic Energy Commission was set up in 1946 and under its provisions the development of atomic energy was transferred from military to civilian control, proper provision for complete liaison with military circles being provided on all matters relating to weapons. It is stated that "the entire investment in the atomic energy project" is now "nearly two and a half billion dollars," say, 600*l.* million. Presumably, this figure includes the original expenditure on the development of bombs, but it is clear that very large sums have been involved in later investigations and that current expenses are very high. It is possible that public opinion in the United States is satisfied that these expensive activities are justified merely from the military point of view, but it may well feel some satisfaction that the Commission can report progress in more peaceful directions.

It is clear that "a considerable area of technical and other information must be kept secret under present conditions," but it has been announced that "the end point of our manufacturing operations takes place at Los Alamos, New Mexico, where U 235 from Oak Ridge, the plutonium from Hanford and other necessary components are brought together to make a finished bomb. The operations here conducted for us under contract by the University of California are necessarily of the highest degree of secrecy." It is added that "if these bombs are never needed for destructive purposes, the atomic material is easily re-adapted for peaceful use." The Commission operates a "huge, scattered, complex atomic energy enterprise" with branches and activities in many parts of the United States, but the main plants are at the locations mentioned above: Hanford, on the Columbia River, in the State of Washington; Oak Ridge, in Tennessee; and Los Alamos, in New Mexico.

The Hanford works, "half as large as Rhode Island," which were designed and constructed by the E.I. du Pont de Nemours Company, and are operated by the General Electric Company, manufacture plutonium. The Oak Ridge factory, operated by the Carbide and Carbon Chemicals Corporation, is mainly concerned with the separation of the isotope U 235 from U 238, which constitutes 99·3 per cent. of natural uranium. The Oak Ridge plant also incorporates the Clinton national laboratory, which is the principal centre for the production of radio isotopes. Originally operated by the Monsanto Chemical Company, it was taken over by the University of Chicago on December 31, 1947. It is from this laboratory that the most direct contributions from atomic-energy research to peace-time service has proceeded. More than 100 varieties of radio isotopes have been produced, mainly for use as tracer elements in medical work, but which have also found application in agriculture and engineering. As an example of agricultural application, the Bureau of Plant Industry is studying the action of phosphate compounds in the soil, by means of radio-phosphorus, with the idea of improving fertilisers. Mr. Waymack has said that "the use of tracer atoms may well lead to such improvements in fertilizing methods, in combating plant and animal diseases, and weeds and pests, as to increase agricultural productivity enough to outweigh the total cost of our atomic energy development up till now."

As an example of radio-isotope technology in engineering, the Massachusetts Institute of Technology has employed the method to investigate the fundamental mechanism of friction and in research on the surface layers on the piston rings and cylinder walls of aero engines. Radioactive tracers are also being used in metallurgical research. The radio isotopes are shipped from the laboratory in glass bottles inserted in air-tight stainless-steel cylinders, the cylinder, in turn, being in a lead shield supported inside a wooden box. The thickness of the lead shield varies from half an inch, depending on the amount and energy of the radioactive substance. All packages are checked for radiation at the surface after making up and, if necessary, are re-packed with a thicker shield, but some air lines refuse to handle them, fearing interference with navigation instruments. The Clinton authorities, however, maintain that the radiation intensity at the surface of the containers is about the same as that at the dial of the pilot's wrist watch.

There are some indications that the Atomic Energy Commission is concerned with the future of fundamental research in the field with which it is concerned, and the supply of adequate staffs of sufficiently able investigators. Considerable stress is being laid on the necessity for education and it is possibly with the idea of enlisting a wider range of academic workers that the Los Alamos plant and the Clinton laboratory are being operated by the Universities of California and Chicago. These are not the only examples. The Brookhaven National Laboratory, on Long Island, is controlled by nine associated eastern universities, and the Argonne National Laboratory, at Chicago, has 29 participating mid-west universities. Mr. Sumner T. Pike, a member of the Commission, has pointed out that "basic science or pure research, for which we have formerly depended very highly on Europe, has been badly interrupted and may not be available as freely to this country as before the war . . . not only most of the basic science for the atomic energy project came from Europe, but also in other lines the Europeans have furnished the pure ideas." In addition to the National Laboratories, it is felt to be desirable that the universities shall engage in independent investigations. A difficulty is cost of equipment and some universities are endeavouring to obtain financial assistance from industry.

NOTES.

THE INSTITUTION OF ELECTRICAL ENGINEERS.

IT is announced that the Council of the Institution of Electrical Engineers have awarded the Faraday Medal for 1948 to Professor M. L. E. Oliphant, F.R.S., for his distinguished work in nuclear physics and his original discoveries in physical science, particularly in the realm of electromagnetic oscillations, their production, study and use. Professor Oliphant was educated at Adelaide and Cambridge, and, after acting as Assistant Director of Research at the Cavendish Laboratory, was appointed Poynting Professor of Physics at the University of Birmingham in 1937. It is also announced that Colonel Sir T. F. Purves, O.B.E., and Admiral of the Fleet Sir J. H. D. Cunningham, G.C.B., M.V.O., have been elected honorary members of the Institution; the former for his distinguished work in electrical engineering and his services to the Institution, and the latter for the outstanding part played by him in stimulating the application of electrical technique in the Royal Navy, and the contributions made by officers of the Royal Navy to the applications and developments of electrical science and engineering. It may be noted that this dual election of honorary members implements a new by-law, which empowers the Council, once in three years beginning January 1, 1948, to elect as honorary member someone who is not already a member of the Institution, in addition to the one honorary member who may already be elected each year, and upon whom no such restriction is placed. Sir Thomas Purves entered the Engineering Department of the Post Office in 1892, and, after holding various positions, was Engineer-in-Chief from 1922 to 1932. He is at present Director of the Cable Makers Association. He served as President of the Institution in 1929. Sir John Cunningham had a distinguished career in the Navy during both Great Wars. He was first Deputy Director and then Director of the Plans Division from 1929-32, and in 1937 was appointed Assistant Chief of Naval Staff (Air) and Fifth Sea Lord. After serving as Rear-Admiral commanding the First Cruiser Squadron, and Flag Officer commanding Force M, he became Fourth Sea Lord and was subsequently Commander-in-Chief, Levant and Mediterranean. He is at present First Sea Lord and Chief of the Naval Staff. He was promoted Admiral of the Fleet on January 21, 1948.

THE SAUNDERS-ROE SR45 FLYING BOATS.

Satisfactory progress has been made by Messrs. Saunders-Roe Limited, Cowes, Isle of Wight, with the construction of the three 140-ton flying boats ordered by the Ministry of Supply in May, 1946. The three boats, at present known by their project designation, SR45, are intended for use on the North Atlantic routes and will carry approximately 85 passengers, the actual number depending on the final layout of the interior. Their use, however, will not be confined to the North Atlantic routes, as they will be equally suitable for medium and long stage services in any part of the world. The three boats are in different stages of completion, the most advanced having the majority of the frames and stringers in position and a considerable portion of the plating riveted thereto. The hulls are of figure 8 section, and when completed the boats will have a span of 220 ft., a length of 148 ft., and a gross weight of approximately 140 tons. The wings will be in five sections and, in addition to carrying the fuel tanks, they will be fitted with thermal de-icing equipment, the hot air for which will be obtained from heat exchangers situated in the engine tail pipes. Similar de-icing equipment will be fitted to the tailplanes, but in this application the hot air will be obtained from combustion heaters. Each boat will be powered by ten Bristol Proteus gas-turbine propeller engines, which will be arranged as two single outboard units and four coupled inboard units. The axes of each pair of coupled engines will be parallel and they will drive contra-rotating airscrews through a reduction gearbox, while the two outboard engines will drive single airscrews. The maximum still-air range will be in the neighbourhood of 5,500 miles, while the cruising speed will be in excess of 350 miles an hour. The four coupled units will be used to drive electrical generators and, in addition, the two innermost units will drive the centrifugal blowers for the air-conditioning equipment. The hulls will be fully pressurised and the cabin air pressure will be equivalent to an altitude of 8,000 ft. The passengers and payload will be accommodated on two decks, the upper one of which will be situated at the intersection of the two circles forming the figure 8, while the lower deck will be at the intersection of the planing bottom with the hull. Several alternative internal layouts have been put forward, including one having separate cabins on the lower deck which will give a degree of privacy and comfort comparable with that found on a modern ocean liner. Although present plans envisage the carrying of some 85 passengers across the Atlantic, it should be pointed out that there is sufficient room within the hulls to accommodate up to 140 passengers; obviously, the aircraft will be confined to short stages should this number be carried.

ELECTRICITY SUPPLY DURING 1947.

The official returns rendered to the Electricity Commissioners show that, during 1947, the total amount of electricity generated by authorised undertakings in Great Britain was 42,759 million kWh, compared with 41,254 million kWh during 1946, an increase of 1,325 million kWh, or 3·2 per cent. These figures seem to indicate that the calls for increased industrial activity and for greater domestic economy have both been in some measure successful. If the need for greater output from industry, which is, of course, largely reflected in electricity consumption, had been accompanied by higher demands on the domestic side, there can be no doubt that the percentage increase would have been even higher than in pre-war years, when they were in the neighbourhood of 10 or 12 per cent. This is proved by a comparison between the figures for the closing months of 1947 and those for the earlier part of the year. In December, 1947, the amount generated was 4,432 million kWh, compared with 4,372 million kWh in December, 1946, an increase of 60 million kWh, or 1·4 per cent. On the other hand, during February and March, 1947, the two months which included the worst of the restrictions on supply, the output was 7,663 million kWh, compared with 7,282 million kWh during the corresponding period of 1946, an increase of 381 million kWh, or 5·2 per cent. It is, in fact, extraordinary that the widespread industrial dislocation, which arose directly from the coal shortage, did not have more effect on the electrical output. It may be pointed out, however, that during the first two months of last year the increase in output over 1946 amounted to 9·8 per cent., although restrictions were in force for a part of that period. It may be added that during 1947 the total amount of electricity sent out, as distinguished from that generated, amounted to 40,173 million kWh, compared with 38,934 million kWh during 1946, an increase of 1,239 million kWh, or 3·2 per cent.

THE WORLD'S SHIPBUILDING.

The total gross tonnage of merchant ships, of 100 tons and upwards, under construction in the shipyards of Great Britain and Northern Ireland continues to increase, it being stated in the quarterly shipbuilding returns of Lloyd's Register of Shipping that the total for December 31, 1947, namely, 2,173,361 gross tons, exceeds by 60,692 tons that for September 30, 1947, and is also greater by 236,299 tons than the aggregate of the shipping which was being built on December 31, 1946. The present total, in fact, has not been exceeded since March, 1922, when the tonnage of merchant ships building aggregated 2,235,998, but it should be borne in mind that, in some cases at all events, prevailing circumstances are imposing delays on the completion of ships, and this may have an influence on the statistics. An encouraging feature, however, is the continued increase in the tonnage intended for registration abroad or for sale. This figure has risen progressively during the past two years and now stands at 671,000 tons, or 30·9 per cent. of the shipping being built in this country. Included are 51 ships, making together 146,832 tons, on which construction was commenced during the December quarter. The above-mentioned total of 2,173,361 tons of ships under construction in this country on December 31, 1947, is made up of 186 steamers, aggregating 980,507 tons, 268 motorships comprising 1,182,475 tons, and 34 sailing ships and barges, making together 10,379 tons. During the quarter under review, 343,521 tons of shipping were commenced in the shipyards of this country and 390,626 tons were launched. The gross tonnage of merchant ships under construction abroad totalled 1,808,996 on December 31, 1947. This is 47,228 tons less than the figure for September 30, when it was noted that returns from Germany, Russia and Japan were not available; these reservations still apply. Of the leading countries abroad, France holds first place with 295,389 tons of shipping under construction, Sweden is second with 261,605 tons, Holland third with 255,199 tons, and Italy fourth with 219,922 tons. During the quarter under review, 276,330 tons of shipping were commenced abroad and 241,389 tons were launched. It is of interest to note that the oil-tank steamers and motorships, of 1,000 tons gross and upwards, at present under construction in the world's shipyards total 84 vessels, representing 742,084 tons, and involving 11 steamers, aggregating 80,690 tons, and 73 motorships, comprising 661,394 tons. Out of these, 50 ships, making together 447,945 tons, are being built in this country; nine ships, totalling 95,000 tons, in Sweden; six ships, comprising 59,699 tons, in France; and five vessels, aggregating 55,036 tons, in Denmark. The vessels being built in the world on December 31 include 19 steamers and 61 motorships, each of between 8,000 and 10,000 tons; 27 steamers and 52 motorships of between 10,000 and 20,000 tons; three steamers of from 20,000 to 30,000 tons; and three steamers of between 30,000 and 40,000 tons.

THE GÉNISSIAT DAM.

On Monday, January 19, Mr. R. Lacoste, French Minister of Production, operated a switch which closed the main sluice gate of the new Génissiat dam, built across the River Rhône, at a point where it is 150 m. (164 yards) wide, some three miles south of Bellegarde and about 20 miles south-west of Geneva. The Génissiat dam, which is of the gravity type and 100 m. (328 ft.) in height, is the first of a number of similar works intended mainly for the purpose of power generation, to be built by the Compagnie Nationale du Rhône. Work was begun on the site in 1937 and was actively pushed forward until 1940. Interrupted as a result of the war and German occupation of France, the work was taken up again towards the end of 1944, and, after proceeding somewhat slowly for a few months, moved forward with increasing speed when materials became available, especially during the years 1946 and 1947. The power station is built into the base of the dam, the water reaching the turbines through steel-lined tunnels, 5·75 m. (about 19 ft.) in diameter, formed in the mass concrete of the dam. Five turbo-alternators, each having a capacity of 65,000 kW, are being installed, two of which, we understand, are now in place. One further set, which will be similar to the other five, is envisaged. Each generating unit is composed of a vertical-axis Francis turbine coupled to an alternator and working under a normal maximum head of the order of 70 m. (230 ft.) and running at 150 r.p.m. Two auxiliary sets, each of 2,000 kW capacity and consisting of a vertical-axis Francis turbine and an alternator running at 600 r.p.m., are also being constructed. The current generated by the main plant is to be stepped up to 220,000 volts, on the site, in three-phase transformers; it will be utilised on various electrified lines of the French National Railways, and will also be available for public supply in Lyons and other French towns.

R.M.S. "ANDES."

Launched at Belfast on March 7, 1939, the S.S. Andes, built for the Royal Mail Lines, Limited, was completed at the outbreak of war. Originally she was to have sailed on her maiden voyage to South America on September 26, 1939, a date which marked the centenary of the company, but by November, 1939, the vessel had been stripped

of her furnishings and converted to a troopship without having sailed in her intended capacity. The vessel has now been refitted by the original builders, Messrs. Harland and Wolff, Limited, and left on her maiden voyage to South America on Thursday, January 22, the work of reconditioning having occupied ten months, which, in view of her original furnishings having been destroyed by enemy action, represents a creditable achievement. The Andes has an overall length of 669 ft. and a moulded breadth of 83 ft., while the gross registered tonnage is approximately 25,700. She has been fitted out to carry 324 first-class and 204 second-class passengers and, in addition, will carry approximately 3,330 tons of refrigerated cargo, together with 4,648 tons of general cargo. There are four complete decks, together with lower and orlop decks extending forward and aft from the machinery space; in addition, there is a forecastle deck, a lower promenade deck, an upper promenade deck and the boat-deck. The hull is divided into twelve compartments by eleven watertight bulkheads and there is a continuous double bottom arranged for the storage of fresh water, water ballast and fuel oil. The propelling machinery was constructed by Messrs. Harland and Wolff, Limited, and consists of twin-screw Parsons-type geared turbines which are supplied with steam at a pressure of 375 lb. per square inch by three Babcock-Johnson boilers. The machinery space is divided into three watertight compartments, the stokehold being in the middle while the generators and main engines are located forward and aft of this compartment, respectively. The engines develop a total of 30,000 shaft horse-power and the service speed of the vessel is 21½ knots; during trials, however, a speed of 23 knots was recorded.

LETTERS TO THE EDITOR.

CREEP AND SHRINKAGE IN REINFORCED CONCRETE.

TO THE EDITOR OF ENGINEERING.

SIR,—May I be allowed a final word to sum up the correspondence between Dr. Hajnal-Kónyi and myself in recent issues of ENGINEERING? It would appear that we are agreed on the main point of discussion—that it is desirable to adopt a plastic, or ultimate-strength, theory for the design of reinforced-concrete members—but differ in our opinions on the procedure which should be adopted until such time as the plastic theories come into more general use. Certainly, the intervening period will be somewhat lengthy; the theories have been known for a number of years and were recommended for column design in a 1934 Code of Practice, but they are still in only very limited use in Great Britain and the United States.

During this period, Dr. Kónyi, apparently, would prefer to retain our present-day procedure, whereas I have suggested that we should attempt to improve it by the incorporation of a higher modular ratio. I consider that this would cut down the dimensions of reinforced members without affecting the factor of safety (with which Dr. Kónyi does not agree) and would prevent design stresses differing greatly from those finally attained. For further consideration of this subject I would refer to an article by Professor A. D. Ross on "The Case for a High Modular Ratio," published in *Concrete and Constructional Engineering*, October, 1946, while I hope myself to present a further analysis at some later date.

Whatever else a higher modular ratio may achieve, however, it would certainly make engineers aware of the inelastic properties of concrete and their effects on the stress-distributions and deflections of reinforced-concrete members. The most satisfactory solution is undoubtedly to teach young engineers the results of recent research, so that they may judge for themselves the relative merits of the various methods.

Yours faithfully,

H. B. SEED.

Harvard Graduate School of Engineering,
Harvard University,
Cambridge 38, Massachusetts, U.S.A.
December 30, 1947.

ENGINEERING UNITS OF FORCE.

TO THE EDITOR OF ENGINEERING.

SIR,—Truly, "the evil that men do lives after them," and Professor Perry's "slug" is a long time a-dying. It was invented because engineering students were not supposed to be able to appreciate "mass," but one can say with full confidence that a student so restricted would never be able to find his way through the maze of modifications and adjustments which the use of the term entails, or to face the far more complex problems which engineering science presents. I, for one, have good reason to regret the birth of this pestilential creature, and the "innate sluggishness" of bad ideas once they are committed to print.

Yours faithfully,

H. WRIGHT BAKER, D.Sc., M.I.Mech.E.
Professor of Mechanical Engineering,
College of Technology,
Manchester, 1.
January 14, 1948.

TO THE EDITOR OF ENGINEERING.

SIR,—The *Concise Oxford Dictionary* defines "slug" as "kinds of shell-less snail destructive to small plants" and as a "bullet of irregular shape; a roundish lump of metal." It would be interesting to know whether Professor Perry, in adopting this name for his unit of mass, had in mind the gardener's pest, as Mr. Lennie implies in his letter on page 40, *ante*, or the lump of matter destined to serve as a missile. The French equivalent of the former would presumably be *une limace* and not *un escargot*, but the latter would surely be the more logical origin for a mechanical unit. It is certainly desirable that a unit should admit of unique specification. It can hardly be a recommendation that the three alternative versions given of the "slug" should be current, or that the one defining it as the mass acquiring an acceleration of 1 ft. per second per second when continuously acted upon by 1 lb. weight should make it a variable unit.

Much confusion would be saved by using the absolute F.P.S. system, which is formally analogous to the C.G.S. system of the physicist, and which is exemplified by Mr. Lennie's equation (2) rather than by his equation (4).

Yours faithfully,

G. F. HERRENDEN HARKER.

University College,
Cardiff.
January 16, 1948.

TO THE EDITOR OF ENGINEERING.

SIR,—It is not possible to adopt a fully self-consistent system based either on the "pound mass" or the "pound force" without abandoning a number of universally accepted units of measurement. This state of affairs has developed because engineers dislike using both the poundal and the slug, and prefer inconsistency to the use of an unaccustomed unit. If a choice has to be made between the two systems, the "pound-force" system would probably be favoured by mechanical engineers, as the units in frequent use, such as pressure in pounds per square inch; work in foot pounds; and torque in pounds-feet, would not then require to be changed to the poundal equivalents. To be consistent, some units would, however, require to be changed; for example, density should then be expressed in slugs per cubic foot and thermal units should also be based on the slug, although in this latter case inconsistency would be unlikely to lead to confusion.

Of the variants on the "pound-force" system given by Mr. Lennie, the only acceptable one, in my opinion, is variant (*c*), in which mass and not force is the fundamental unit. It is regrettable that an easy way out of the difficulty is not possible; and the use of the one word "pound" for mass and force, which incidentally eliminates the need for both the poundal and the slug, will continue to cause confusion and mistakes.

Yours faithfully,

J. G. WITHERS.

Anglo-Iranian Oil Company, Limited,
Chertsey-road, Sunbury-on-Thames.
January 16, 1948.

THE ENGINEERING OUTLOOK.

IV.—THE MACHINE-TOOL INDUSTRY.

THE output of the British machine-tool industry in 1947 ran closely parallel to that of 1946. The latest available figures show that 33,000 "major-cost" machine tools—that is, those not valued at less than 50*l.* each—were completed in the nine months, January to September (Table I, herewith). February was a lean month and the fuel crisis apparently cost the industry about 1,000 machines,

TABLE I.—*Deliveries Ex-Works of British-Built Machine Tools.* (*Monthly Average for Calendar Months.*)

Year.	Metal-Working Machine Tools.			
	Total.		For Export.	
	Number.	Value, £1,000.	Number.	Value, £1,000.
1941	6,744	2,537	—	—
1942	7,982	2,795	—	—
1943	6,350	2,609	—	—
1944	4,927	2,147	—	—
1945	3,957	1,728	—	—
1946	3,756	1,669	1,014	601
1945, July	4,109	1,717	300	315
August ..	2,365	922	177	107
September ..	2,627	1,343	223	137
October ..	3,519	1,286	334	186
November ..	3,000	1,222	267	181
December ..	3,210	1,242	437	291
1946, January ..	4,002	1,702	718	379
February ..	4,572	1,665	787	482
March ..	3,165	1,193	579	358
April	3,356	1,368	794	536
May	3,929	1,523	821	506
June	2,968	1,187	774	390
July	4,528	1,970	1,176	836
August ..	3,108	1,603	1,106	657
September ..	4,074	1,926	1,514	804
October ..	3,856	1,918	1,309	747
November ..	4,036	2,021	1,356	793
December ..	3,483	1,955	1,231	725
1947, January ..	3,994	1,938	1,308	796
February ..	2,809	1,434	1,102	662
March ..	3,826	2,084	1,295	812
April	3,851	1,992	1,329	832
May	3,513	2,004	1,272	869
June	3,981	2,271	1,276	854
July	3,710	2,085	1,312	796
August ..	3,181	1,862	1,111	703
September ..	4,080	2,354	1,430	982

but part of this loss was made up later in the year, and the twelve-months' total may be expected to be very close to the 1946 figure of just over 45,000 machines. The industry has suffered severely from shortage of iron castings, steel, electric motors and bearings, and from low productivity of labour. Although the available statistics do not permit of a fully accurate comparison with the pre-war level of output, it is clear that, almost without exception, the increased capacity created during the war has been lost, and it is probable that the volume of production to-day is slightly below that of 1938.

From every point of view, this situation must be regarded as grave, but two aspects of it call for special emphasis. The first danger arises from the fact that the available supplies of machine tools for British industry as a whole are not sufficient to prevent increasing obsolescence in the nation's workshops, and this at a time when mounting costs of labour and raw materials make the maintenance and improvement of productivity of the utmost importance. The second point is the danger to national security. Three years were needed in which to organise the industry for war in the recent conflict and, apart from improved liaison between machine-tool makers and the Government, the situation to-day is no better than that of 1939.

The situation is the more serious in that its implications do not appear to be widely appreciated. The machine-tool industry itself, however, was not slow to sound the warning as soon as the likely course of events in the post-war period became apparent. In their report on the industry's future, published in August, 1945, the Machine Tool Trades Association said "it is estimated that an output by the British machine-tool industry of 23,000,000*l.*

per annum, at present-day prices, would represent a datum line below which it might be dangerous to sink. If and when production comes down to this level, there should be the most careful investigation in order to ascertain whether a danger point has not been reached . . ." The M.T.T.A. based their "datum line" estimate on an investigation which led to the conclusion that economic and efficient production could not be maintained if output fell below the 1943 level by more than one-third. Strategic factors were also taken into consideration, although readiness for quick expansion was held to be of greater importance than the actual scale of output in this connection.

In fact, the 1945 output, valued at 20,736,000*l.*, fell short of the suggested datum line by nearly 10 per cent. Since 1945, prices have risen by approximately 25 per cent. The value of 23,000,000*l.* in 1945 would be equivalent to nearly 31,000,000*l.* to-day, whereas the final value of the 1947 output of machine tools is unlikely greatly to exceed 24,000,000*l.* In April, 1947, the M.T.T.A. again drew attention to the dangers of low output, when Mr. J. Holland Goddard said in his presidential address that "output is . . . well below the danger minimum laid down by us of 23,000,000*l.*" He added, "The Association has taken the greatest care to ensure that this state of affairs is well known to the authorities and that its significance is fully appreciated by them." The M.T.T.A. may have succeeded in inspiring official appreciation of the gravity of the situation, but, so far, public opinion at large has remained largely indifferent to the situation. Certain sections of the Press campaigned during 1947 for priority in material supplies and in the recruitment of labour, but there was no sign of machine-tool production becoming a national issue.

It might be argued, indeed, that the M.T.T.A. and those organs of the Press concerned were prejudiced, to some extent, in favour of an expanded machine-tool output, but consideration of the machine-tool position in British industry as a whole offers powerful support for their arguments. In November, 1940, a census of machine tools in the hands of the Government and of privately-owned firms was attempted. The census was not entirely successful, but it did show that the working machine-tool population of the United Kingdom was then about 700,000. If the known new supplies are added to this figure and reasonable allowance is made for the scrapping of obsolete machines, the working machine-tool population at the beginning of 1947 was approximately 850,000. It is generally accepted that, before the war, the average age of machine-tool equipment was about 20 years. The large numbers of new tools installed during the war years must have lowered this figure substantially, but the present rate of supply would, if unaltered, eventually give rise to a higher average age than the pre-war estimate. In 1946, approximately 35,000 machine tools were available for purchase in this country. This is equivalent to very slightly more than 4 per cent. of the machine-tool population and implies replacement not more frequently than once in every 25 years.

In 1947, the situation deteriorated still more, from the same industrial point of view. Production figures for the first three quarters of the year (Table I) suggest that just over one-third of the total production ex-works was destined directly for export. In the full year, this would amount to about 15,000 tools, leaving something over 29,000 for other purposes. Of these, however, a number have found their way overseas through the hands of merchants, as is shown by the fact that the Board of Trade's export figures, quoted in Tables II and III, herewith, are considerably larger than the ex-works export figures given in Table I. It must be assumed, therefore, that about 18,000 British-made machine tools were exported during 1947, leaving about 26,500 for use in the British engineering industry. To this figure must be added imports which, up to November, 1947, came in at the rate of approximately 5,000 tools a year, as is shown in Table IV, on page 90. The total available for home buyers was thus in the neighbourhood of 31,500 tools, a rate of supply which would need 27 years to replace existing industrial equipment.

It does not follow, of course, that this low replacement rate is representative of British engineering as a whole. A large section of industry does maintain its plant in an up-to-date condition, and this is particularly the case in the big firms whose scale of turnover makes machine-tool running costs comparatively low. It must be remembered, however, that a large part of British engineering is carried out by small firms having fewer than a hundred employees each, and it is in these smaller enterprises that the growing obsolescence of equipment is the most marked. This, in turn, means that a very powerful factor is operating against increases in the productivity of labour at a time when, above all, such increases are desirable in the national interest.

The outlook for 1948 promises no improvement in the supply of machine tools for British industry. On the contrary, in the autumn of 1947, a new export programme was laid down by Government for the industry, raising the export quota from the 1947 level of 50 per cent. (by value) of output to 60 per cent., which level it is hoped to reach by the middle of 1948. The announcement of the new export target preceded, but was complementary to, the White Paper on *Capital Investment in* 1948 and Sir Stafford Cripps's letter to industry, dated December 12, 1947, on the same subject. Government policy may be summarised as a request to industry to "make do and mend" in the interests of export, and, failing a substantial increase in the output of machine tools at home, or an increased import rate, the replacement rate of machine tools in use in British industry must fall to a still lower level than that of 1947.

TABLE II.—*United Kingdom: Exports of Machine Tools by Classes*, 1938, 1945, 1946 *and* 1947.

	1938.	1945.	1946.	1947.	
				*9 months.	11 months.
Weight (tons).					
Boring mills	1,673	1,148	2,000	2,475	3,029
Drilling machines	2,532	1,239	3,877	3,612	4,323
Grinding machines	2,792	1,480	2,728	3,302	4,199
Lathes†	6,727	6,663	10,497	9,690	12,508
Milling machines	1,798	1,712	3,252	3,340	4,006
Planing and shaping machines	3,535	1,822	2,364	2,334	2,925
Presses, punching and shearing machines	1,470	1,457	2,280	3,864	4,728
Power saws	—	—	818	694	805
All other sorts, including reconditioned, and parts	3,595	3,491	7,633	9,350	12,359
Total	24,122	19,012	35,449	38,661	48,882
Value (£1,000).					
Boring mills	235	212	542	649	778
Drilling machines	444	275	992	972	1,187
Grinding machines	736	403	877	1,122	1,415
Lathes†	1,441	1,798	3,133	3,167	4,104
Milling machines	424	504	1,171	1,184	1,386
Planing and shaping machines	420	308	497	521	665
Presses, punching and shearing machines	146	292	396	743	915
Power saws	—	—	177	169	201
All other sorts, including reconditioned, and parts	627	744	1,795	2,061	2,761
Total	4,473	4,536	9,580	10,588	13,412
Value per ton exported (£).					
Boring mills	140	184	221	—	257
Drilling machines	175	222	256	—	275
Grinding machines	263	272	321	—	338
Lathes†	214	270	300	—	328
Milling machines	236	294	360	—	346
Planing and shaping machines	119	169	210	—	227
Presses, punching and shearing machines	99	200	174	—	194
Power saws	—	—	216	—	247
All other sorts, including reconditioned, and parts	174	213	235	—	223

* Included for comparison with output figures in Table I.
† Including screw machines.

TABLE III.—*United Kingdom: Exports of Machine Tools by Countries*, 1946 *and* 1947.

Country.	1946.		1947*(11 months)	
	Weight (Tons).	Value (£1,000).	Weight (Tons).	Value (£1,000).
Palestine	—	—	538	167
Union of South Africa	2,454	647	3,581	912
British India	5,484	1,489	9,368	2,207
Australia	2,234	573	4,340	1,154
New Zealand	759	198	953	312
Other British countries	3,112	799	3,497	1,060
Russia	150	21	1,160	206
Netherlands	2,661	791	4,339	1,189
Belgium	1,807	506	1,716	514
France	9,105	2,397	4,393	1,237
Italy	8	5	21	10
Sweden	—	—	2,334	694
Denmark	—	—	1,123	349
Switzerland	—	—	1,046	292
Spain	—	—	910	270
Turkey	—	—	434	165
Other foreign countries	7,675	2,155	9,429	2,675
Total	35,449	9,581	49,182	13,413

* 1947 figures not completely comparable with previous years.

The post-war structure of the export market by countries of destination is indicated in Table III. As a hard-currency earner, the industry's greatest successes during 1947 were in Sweden and Switzerland, where sales totalled, respectively, 694,000*l.* and 292,000*l.* in the period January to November. There were, in addition, small sales to Portugal, to South American countries, and to Canada, though not on a sufficient scale to justify separate listing in the preliminary figures published by the Board of Trade. The main dollar-earning market, in the United States, however, is almost entirely closed to the machine-tool industry by the combination of internal competition with a high protective tariff.

Inside the Empire, the industry's best customer was India, which was buying at the rate of 2,400,000*l.* a year in 1947, followed by Australia, with 1,260,000*l.*; while, in the foreign list, France was buying British machine tools to the value of 1,350,000*l.* a year, and the Netherlands at 1,300,000*l.* a year. Russian purchases, which were very large during the war and fell almost to zero in 1946, were resumed during 1947 and are likely to show further expansion during 1948 as a result of the recently-signed Anglo-Russian trade treaty.

Throughout the post-war period, the industry has enjoyed the advantage of the world-wide sellers' market, and the demand for its products has continued to mount despite delivery periods ranging from six months to two years, and occasionally longer. Records of outstanding orders at works for major-cost machine tools from home and overseas customers are compiled by the Ministry of Supply (Table V, on page 90), and, so far, show no sign of a recession in the sellers' market overseas. The value of outstanding overseas orders rose almost without break from 13,120,000*l.* in August, 1946, to 16,492,000*l.* in September last. This last figure is equivalent to more than two years' ex-works deliveries for export at the 1947 rate. It is, no doubt, swollen by double ordering, but even so it implies a high degree of probability that the industry will have no difficulty in reaching its 1948 export target.

It is of interest to examine the 60-per cent. export target for 1948 in comparison with the industry's export record in the post-war period. In the second half of 1945, the industry's ex-works deliveries for export were at the monthly rate of nearly 300 machine tools, valued at slightly more than 200,000*l.* By 1947, the monthly rate had risen to 1,300, and the monthly value to more than 800,000*l.* These figures indicate the scale of expansion that has been achieved already, but, as was mentioned above, are not fully representative of exports, since they do not include those machines which find their way overseas through the hands of British merchants. From the *Trade and Navigation Accounts*, it appears that the total machine-tool exports, including merchants' sales, amounted to 10,588,000*l.* in value in the first nine months of 1947. This figure is not directly comparable with the output figures in Table I, since it includes "minor-cost" tools—that is, those costing less than 50*l.*—whereas the output figures are for "major-cost" tools only. If, however, the export figure for January to September, 1947, be compared with the output figure of 18,024,000*l.* for the same period, it will be seen that the industry reached its 50-per cent. export target, provided that the value of minor-cost machine tools exported was not more than 1,500,000*l.* The figures do not permit the argument to be pressed to an exact conclusion, but it seems probable that, in fact, the industry did justify its own claims to have reached its target.

Machine-tool exports in 1947 far exceeded any previous year's achievement, both in value and tonnage. On the showing of the first eleven months, the year's tonnage will be over 53,000, which compares with 35,449 tons in 1946 and with a previous record in the inter-war period of 24,242 tons in 1920; that is, in the corresponding period immediately after the first world war. Impressive as these figures are, there is every reason to believe that they can be exceeded during 1948, but there are a number of danger signals in the export position on the medium-term view. The first is the general difficulty of the end of the sellers' market, which must come sooner or later to machine-tool exporters, as to other exporters. Much of the post-war demand has been for the re-equipment of industries damaged or run down during the war years, and, inevitably, the completion of this phase will bring a recession in world demand.

Next, it is of interest to consider what types of machine tools are being sold overseas. An analysis made during a sample period of 1947 showed that 26 per cent. by number of exported machine tools were lathes, 18 per cent. were drilling machines, 12 per cent. were grinding machines, and 9 per cent. were milling machines. Capstan and turret lathes accounted for about 9½ per cent. by number and automatics less than 1 per cent. In terms of cash, lathes were the biggest money-earners, followed by capstan and turret lathes, milling machines, and drilling machines. It will be seen that lathes and drilling machines accounted for 44 per cent. of the exports by number, while their value was about 27 per cent. of the total.

The market for this type of machine is particularly vulnerable to competition from new manufacturers of machine tools, who made their appearance during the war and have since become established. Competition of this type is growing rapidly in the Dominions. In Australia, for example, machine-tool manufacture before the war was confined to three or four small firms, each employing less than 50 operatives, but there are now at least a dozen well-established firms, capable of supplying a growing proportion of Australia's machine-tool needs. Similar developments have taken place in Canada and South Africa and in India, and these changes, of course, are not confined to Empire markets. The implication is that to maintain exports in the long run, the British industry must show itself capable of increasing concentration on the more complicated machines, which, as yet, are not manufactured in the newly industrial countries.

A further export problem is likely to arise on the question of prices. Traditionally, the British industry has enjoyed an advantage over American competition in that British prices have been substantially below those of similar machines from United States workshops. During the post-war period, however, British prices have risen much more sharply than has been the case in the United States and at least part of the advantage has been lost. This development is of little importance so long as the world sellers' market is maintained, but a resumption of intense selling competition is likely to find British manufacturers less favourably placed than in the inter-war years. The cost position, therefore, is of the utmost importance, and any further increases during 1948 must be regarded as danger pointers for the future of the export market.

For the home industrialist, the volume of output will be the most important consideration during 1948. To him, the increased export quota will mean still longer waits for the delivery of machine tools on order, and he will hope that increased total supplies will do something to ease the situation. In passing, it may be of interest to compare the present volume of production with the pre-war rate. The Machine Tool Trades Association estimated the value of the industry's output at 14,000,000*l.* in 1938, although no record of the number of machine tools produced is in existence. Prices, however, have risen by around 90 per cent. in the intervening nine years and the 1947 output, of a total value about 24,000,000*l.*, would be equivalent, therefore, to something over 12,500,000*l.* at 1938 prices. The actual number of machine tools produced in 1947 was, therefore, probably less than it was in 1938. Against this must be set the fact that the modern machine has a higher productivity than its predecessor of 1938, but it is also true that the engineering industries as a whole have greatly expanded since 1938, and that the home market for machine tools has increased in proportion. On balance, there is no doubt that the British engineer is worse off from the point of view of available tool supplies than he was immediately before the war.

TABLE IV.—*United Kingdom: Imports of Machine Tools, 1937 to 1947.*

Yearly, Quarters.	Value (Tons).	Value (£1,000).	Value per ton (£).	Index of Imports (value), 1937=100.
1937, 1st ..	8,249	1,613	193	100
2nd ..	8,846	1,553	175	97
3rd ..	7,920	1,689	213	105
4th ..	6,576	1,357	199	84
1938, 1st ..	7,158	1,450	202	90
2nd ..	5,638	1,157	205	72
3rd ..	5,040	1,103	218	68
4th ..	6,018	1,309	217	81
1939, 1st ..	6,501	1,452	223	90
2nd ..	8,134	1,699	208	105
3rd ..	6,905	1,943	281	120
4th ..	8,832	2,617	296	162
1940, 1st ..	12,152	4,108	337	245
2nd ..	14,183	5,057	353	314
3rd ..	15,561	4,881	315	302
4th ..	30,227	13,736	455	852
1941, 1st ..	22,617	10,388	450	642
2nd ..	23,520	10,954	467	678
3rd ..	20,644	9,805	477	607
4th ..	30,761	6,465	212	400
1942, 1st ..	12,085	6,133	510	380
2nd ..	8,732	4,640	532	287
3rd ..	11,081	5,933	539	366
4th ..	11,372	4,125	363	256
1943, 1st ..	6,169	2,780	450	166
2nd ..	13,200	7,869	595	487
3rd ..	10,344	6,386	620	396
4th ..	9,763	5,557	570	345
1944, 1st ..	5,869	3,372	575	205
2nd ..	4,028	2,323	577	143
3rd ..	2,040	1,257	615	78
4th ..	2,061	1,240	605	77
1945, 1st ..	1,726	1,106	640	69
2nd ..	1,455	810	560	50
3rd ..	1,777	885	500	55
4th ..	1,500	600	400	38
1946, 1st ..	1,822	463	253	29
2nd ..	1,219	589	485	36
3rd ..	1,940	596	307	19
4th ..	1,810	609	336	38
1947, 1st ..	3,533	979	272	61
2nd ..	2,737	1,157	423	72
3rd ..	3,476	1,266	364	78
4th .. (2 months only)	3,142	785		

Note.—1947 figures are not completely comparable with previous years.

TABLE V.—*Orders Outstanding for Major-Cost Machine Tools.*

Date.	Home.		Export.		Total.	
	No.	Value.* (£1,000)	No.	Value.* (£1,000)	No.	Value.* (£1,000)
1945—						
December	30,035	—	13,392	—	43,427	—
1946—						
January	30,406	—	14,559	—	44,965	—
February	30,396	—	15,384	—	45,780	—
March ..	31,621	—	16,559	—	48,220	—
April ..	32,563	—	17,459	—	50,022	—
May ..	33,835	—	18,943	—	52,778	—
June ..	34,389	—	19,395	—	53,784	—
July ..	35,567	—	20,509	—	56,076	—
August† ..	24,030	16,243	17,450	13,120	41,480	29,363
September	24,976	16,862	22,947	14,524	47,923	31,385
October ..	25,962	17,660	21,740	14,587	47,702	32,247
November	27,527	18,758	22,701	14,976	50,228	33,734
December	28,269	19,339	23,295	15,485	51,564	34,824
1947—						
January ..	28,643	20,197	23,047	15,478	51,690	35,674
February	29,989	20,977	23,232	16,014	53,221	36,991
March ..	30,470	20,630	23,647	15,975	54,117	36,605
April ..	30,558	21,320	19,117‡	15,627	49,675	36,947
May ..	30,748	21,566	18,950	15,638	49,698	37,204
June ..	30,745	21,870	18,663	15,548	49,408	37,418
July ..	30,750	22,117	18,475	15,840	49,225	37,956
August ..	30,385	21,935	18,425	15,995	48,810	37,930
September	29,766	21,878	19,261	16,492	49,027	38,360

* The value of orders outstanding was not recorded before August, 1946.

† From August, 1946, major-cost machines were specified as those valued at 50*l.* and over, whereas, before this date, the value was set at 30*l.* and over.

‡ Due to transfer of certain machines to "low-cost" category.

During 1947, the industry's production target for 1948 was put at 25,000,000*l.* in terms of prices then ruling, but subsequent rises in price have made it difficult to interpret this figure in terms of volume of production. Output has been restricted by a series of bottlenecks in iron castings, steel, ball bearings and motor supplies. Of these, the iron-castings and steel positions showed marked improvements towards the end of 1947. Machine-tool makers derived some benefit from the rising productivity of the foundry industry, and some manufacturers were able to mitigate the shortage of castings by the partial substitution of fabricated-steel assemblies. Steel supplies proved less restricted than was feared during the fuel crisis in February, 1947, shortly after which manufacturers were warned that allocations in the second and third quarters would be cut by 50 per cent. In fact, the threatened cuts did not fully materialise. From one source or another, many firms found it possible to maintain steel supplies at pre-cut level, while others were in a strong stock position. Towards the end of the year, the record level of output reached by the steel industry offered grounds for hoping that the steel position was set for steady improvement. The latest developments of the Marshall plan, however, with its insistence on steel for Europe, will mean less imported steel for this country. Despite the increased domestic output of steel, it now seems improbable that the machine-tool industry will receive allocations greater than those of the last quarter of 1947, and this factor alone may well prove sufficient to limit the 1948 output to a scale very close to that of 1947.

The shortage of electric motors has been fully as serious as the shortage of iron and steel in the post-war period, and, as ferrous supplies improved during 1947, the motor position became the industry's most serious bottleneck. Manufacturers receive a monthly quota of electric motors, but in recent months few of them have been getting more than 75 per cent. of their requirements. This shortage has been one of the chief contributing factors to the long delays in machine-tool deliveries, and it is not uncommon to find that otherwise completed products are held up for periods of up to six months, pending the arrival of the necessary electric motors. The situation is aggravated by lack of motors from overseas, for the dollar position does not permit substantial purchases from the United States. Germany, which was always a ready supplier in pre-war days, is out of the market, temporarily at least, and experimental purchases from elsewhere, for example, from Italy, have proved prohibitively costly.

Electric-motor manufacturers have had their own difficulties, notably shortage of electrical sheet, but there appears to be some hope of an increase in output during 1948. The machine-tool industry absorbed about 50,000 electric motors in 1947, most of them in the low horse-power ranges, and would require about 65,000 to achieve the 1948 production target. Even this small margin is critical in the present motor shortage, and, although improved supplies may be expected, it is not likely that the machine-tool makers' requirements will be met in full.

Inadequate supplies of ball and roller bearings have given rise to a shortage almost as acute as that in electric motors. Like the motor manufacturers, bearing makers are faced with the difficulty of making an output little greater than it was in 1938 meet the needs of to-day's considerably expanded engineering industries. Imports during 1947 were less than one-third of what they were in 1938, because of lack of supplies from Germany and the currency difficulties of buying in Sweden, the United States or Switzerland. Fortunately, the machine-tool industry is mainly interested in standard bearings and has few special requirements. The total need, at the 1947 level of output, is of the order of 400,000 complete bearings, a quantity which is small in relation to the national output, and probably not more than a fortnight's production for one of the leading bearing manufacturers. Even so, the shortage of bearings, like that of motors, pervades a wide range of industries, and the machine-tool industry's hopes of an improvement lie rather in an increase in the output of bearings, or in imports, than in more preferential treatment. Both these favourable developments are probable during 1948 and, in particular, bearing makers in this country should begin to show some benefits

from the projects to increase capacity, which they have had in hand for some time. In sum, therefore, it seems likely that supplies of ancillary equipment will show some improvement during 1948, but that the steel position may not permit full advantage to be taken of these developments.

The labour employed in the metal-working machine-tool industry during 1947 averaged about 36,500 operatives in those firms where the number of employees was 11 or more. To this must be added about 2,000 in the smaller concerns, where employment was less than 11 per firm, making a total of 38,500. During the war, the industry was protected by the Essential Works Order, but the lifting of the Order in May, 1946, meant that all the younger men, up to the age of 28, became liable for national service. The age structure of the labour force thus took a sudden shift for the worse, and the shortage of young trained labour was accentuated by the difficulty in obtaining recruits at school-leaving age. There have been revolutionary changes, therefore, in recruitment and training schemes. Apprentice schools, combining higher education and intensive practical instruction with attractive terms of articles, have been introduced by a number of firms where hitherto the young employee followed a somewhat haphazard course in arriving at the "skilled" status.

It is too soon, however, for the benefit of these developments to be felt, and employers continue to complain of the labour shortage, which is particularly acute in the skilled trades. Here, as always, the machine-tool trade suffers a continuous loss of trained personnel to other industries and the wage rates now ruling have increased the flow. Foundry workers have presented a further problem. Young labour is difficult to find, even by present standards of stringency, and the nature of the work in many cases prevents mechanisation of foundries, which might provide an attraction. The manager of a typical machine-tool foundry in Halifax said that during 1947, he had 20 moulders at work, as against 32 before the war, and that he saw little prospect of improvement.

In view of the overall labour situation in British engineering to-day, there is little hope that the machine-tool industry will be able to increase its labour strength during the present year. Increased output must depend, therefore, on increased productivity of the existing labour. There is no doubt that productivity to-day is lower than it was before the war. Employment in the industry in 1938 was around 28,000 and it appears, therefore, that a substantially larger labour force is required to-day to produce much the same volume of output. This is confirmed by the experience of individual manufacturers, a number of whom estimated the decline in their output per man hour at 20 to 35 per cent. in the summer of 1947. It is possible that there has been some improvement in productivity since then, and the general upward trend in national industrial activity would suggest this to be the case. Even so, productivity can hardly have recovered to the 1938 level, and it is of interest to consider the causes. Most important are the dislocations of production caused by long waits for supplies and, in particular, for castings, motors and bearings; and to these must be added the increased average age of employees, mentioned above. It is true, nevertheless, that, despite these difficulties, a few firms have managed to increase their productivity by the use of time study and similar methods calculated to adjust the available labour more closely to present production difficulties. These isolated successes suggest that the productivity of the industry as a whole can be raised, and suggest, further, that this problem will be one of high importance to machine-tool managements during the present year.

The year 1948 is likely to see the end of the disposals scheme, and the curtailment of machine-tool supplies from this source will increase the demand for new machines. From the beginning of the Government scheme in March, 1945, to September, 1947, a total of 175,000 to 180,000 machine tools were disposed of, and it is generally agreed that this task was accomplished without damage to the interests of machine-tool builders. The total value of sales over the 2½-year period was nearly 40,000,000*l*., and the average selling price per tool was 200*l*. to 250*l*. Most of the tools sold through the scheme went to home industry, as may be gauged from the fact that overseas sales were of the order of 500,000*l*., while gifts to foreign Governments totalled 150,000*l*. Contrary to expectations, the sale of second-hand machines did not fall off during 1947. During the summer months of June, July and August, for example, sales were valued at 1,000,000*l*., 1,250,000*l*. and 1,250,000*l*., respectively; a level very close to the average rate of sale throughout the life of the disposal scheme. It is estimated that the total number of machine tools which the Director of Disposals will be called upon to handle will be approximately 220,000, and that about 40,000 remained for disposal from September, 1947. It is probable, therefore, that the existing disposals scheme will be wound up during 1948, although it may be found necessary to maintain a similar organisation on a smaller scale to handle the smaller quantities of Government surplus machine tools which will become available from time to time.

One of the most important events in the machine-tool world during 1947 was the exhibition organised at Chicago in September by the National Machine Tool Builders Association. The exhibition showed the modern trend towards ever-increasing specialisation, taking full advantage of higher cutting speeds, and rapidly imposing methods of electrical control. One firm demonstrated a giant crankshaft-milling machine capable of removing excess metal from the counterweights and milling the crankpins to required diameter in 55 seconds. For this particular product it was claimed that six of them could replace 18 of the type of machine now in general use. A new type of special-purpose machine, which has also made great headway in the United States, is the multi-station automatic, in which a single part, requiring several machining processes, is moved automatically over an integrated line of tools with minimum demands on the attention and skill of the operator. An example of this was a unit operated by a single skilled man but combining ten complete gear-cutting machines, each with its own motor and timer, capable of handling ten different types of gears, or of simultaneous work on ten gears of the same type.

In this country, the Machine Tool Trades Association have planned their first post-war exhibition, to be opened at Olympia in August, 1948. Here again, it is likely that the emphasis will be on special-purpose tools and on new developments in electric and hydraulic control. British design has been influenced recently by the increase in cutting speeds resulting from improved cemented-carbide cutting tools. This is shown in the increased power of driving motors and wider ranges of speed in gearboxes. Simultaneously, accuracy requirements are becoming more exacting, while increased speeds also demand a study of operating convenience, resulting in such developments as pre-selected and power-operated speed-changing. Grinding machines are assuming growing importance, both inside the machine-tool industry and as a product; for example, the grinding of beds and slideways, which was an innovation during the war, has now become standard practice, while the beds of some machines are being flame-hardened with great success. There have been also great improvements in the technique of centreless thread-rolling and negative-rake milling, and it is also gratifying to note that British jig-boring machines of high quality are becoming serious competitors to the foreign products which have been found hitherto in most British tool rooms.

The skill and craftsmanship of the British industry are able, as always, to face world competition with confidence; it is the solution of managerial problems that will most tax the industry in the immediate future. Mounting costs, low productivity of labour, and the perennial difficulty of financing development work in a home market that is far smaller than that of their main competitor, are the hurdles that British machine-tool makers must pass to maintain their traditional position in the world market. In all these, 1948 is likely to prove crucial, and success or failure during the coming months may well determine the industry's future for the next decade.

PROGRESS OF ELECTRICITY SUPPLY IN SHEFFIELD.

A SUPPLY of electricity was first given in Sheffield in 1886, when Mr. John Tasker installed three horizontal compound condensing engines in Sheaf-street to drive 2,000-volt series arc-lighting generators, each of which was capable of carrying a load of 50 lamps. Three years later, a 35-kW, 2,000-volt single-phase Mordey alternator was provided to supply incandescent lamps through transformers on the consumers' premises, distribution both for this system and the arc lighting being by overhead mains. In 1892, the Sheffield Electric Light and Power Company was formed, while two years later, a new station, also in Sheaf-street, was opened, the plant consisting of two 100-kW, one 50-kW and one 35-kW Brush-Mordey alternators. This undertaking was acquired by the Corporation in 1898, and in 1901 the system of supply was changed to two-phase at a pressure of 200 volts and 50 cycles per second. In the meantime, the Sheaf-street station, although it had been extended, had become inadequate to meet the increasing demands; and a new station was therefore opened at Neepsend, the plant consisting of two 1,500-kW Parsons turbo-alternators. A 4,000-kW set was installed in 1909, while three years later the conversion of the two-phase system to three-phase was begun. A 6,000-kW machine was added at the same time and another in 1915.

The output increased from 21,500,000 kWh in 1913 to 172,500,000 kWh in 1919. Additional generating plant therefore became necessary, and in 1916 it was decided to build a new station at Blackburn Meadows. This was opened in 1921, when four turbo-alternators with a combined capacity of 28 MW were inaugurated by the Duke of York (now H.M. King George VI). A second station on an adjoining site, with a capacity of 25 MW, was opened by the Duke of Kent in 1933, while in the same year both Blackburn Meadows and Neepsend were connected to the grid. In the meantime, the area of supply had been largely extended; and in 1934 the laying of a 33-kV distribution system was begun, particularly so that the large steelworks in the city could be supplied. Further extensions, consisting in all of four 30-MW sets, were made at both Neepsend and Blackburn Meadows between 1936 and 1938, while in 1939-40 two 50-MW sets were added to the latter station, the steam conditions in all cases being 625 lb. per square inch and 850 deg. F. During the recent war the sale of electricity increased from 552 million kWh in 1939 to 908 million kWh in 1944, the maximum demand during the same period rising from 168·7 to 228·5 MW. In addition, a large amount of electricity was exported to the grid so that the maximum demand on the two stations reached nearly 273 MW. In 1944, authority was received for the installation of a 50-MW set at Neepsend and this was formally inaugurated by the Minister of Fuel and Power (the Rt. Hon. H. T. N. Gaitskell, M.P.) on Saturday, January 10, 1948.

The new set at Neepsend is supplied with steam at a pressure of 625 lb. per square inch and a temperature of 850 deg. F., from three tri-drum boilers, which were constructed by the Stirling Boiler Company, Limited, 32, Farringdon-street, London, E.C.4. These boilers are fired by Babcock and Wilcox chain-grate stokers and operate in conjunction with Green's economisers and Stirling pendant superheaters. The ash is discharged, through Babcock and Wilcox submerged paddle ash pans, on to a belt which conveys it to a dumping ground above the station. Grit is removed by Howden scroll collectors, and the gases exhaust into a steel chimney lined with brick below and gunite above. The draught plant and air heaters were supplied by Messrs. James Howden (Land), Limited, 195, Scotland-street, Glasgow, C.5. The turbo-alternator is of the Metropolitan-Vickers two-cylinder type and generates three-phase current at 11 kV when running at 1,500 r.p.m. It exhausts into a condenser, which was constructed by the same firm, the cooling surface being 49,000 sq. ft. To supplement the supply of cooling water from the River Don, a cooling tower 250 ft. high and capable of cooling 3½ million gallons of water per hour from 92 to 80 deg. F. has been erected by Mitchell Engineering, Limited, Peterborough. The output of the new set is stepped up to 33 kV and is controlled at that voltage by a switchboard constructed by the Metropolitan-Vickers Electrical Company, Limited, Manchester. This consists of a number of metal-clad single-break oil-immersed circuit breakers, with rupturing capacities of 750 and 1,000 MVA, and is connected to the original 11-kV Reyrolle switchboard through English Electric transformers.

Authority has also been given for the erection of a second 50-MW set at Neepsend, the completion of which is scheduled for 1949. The cooling tower associated with this extension, however, is almost completed. The general manager and engineer of the undertaking is Mr. J. R. Struthers, M.I.E.E., who has been responsible for the latest extensions.

NOTES ON NEW BOOKS.

Applied Heat for Engineers. By DR. J-B. O. SNEEDEN. Blackie and Son, Limited, 66, Chandos-place, London, W.C.2. [Price 12*s.* 6*d.* net.]

THIS addition to the long list of text-books on heat and heat engines is of an elementary nature, put forward as covering the requirements of Part I of the examination for the London B.Sc. (Eng.) and equivalent professional tests. Its contents are mostly concerned with the usual calculations about steam and gases, which leave little scope for originality. The simple temperature-entropy diagram is explained, but no mention is made of the more practically useful Mollier diagram. When dealing with machinery and apparatus, the book displays rather a lack of proportion. Instruments, for example, are given some 36 pages, of which 14 are devoted to pyrometers, while the steam engine itself is disposed of in about 10 pages. Turbine machinery is also dealt with very sketchily, three lines only being allotted to the principle of the reaction turbine, of which no further description is given. Condensing plant is omitted entirely. Boilers, superheaters, economisers and air-heaters occupy nearly 11 pages, but more than two-thirds of this space is taken up by illustrations of a catalogue nature. Of exercise questions there are plenty of examples, worked out and otherwise, but the student would need much more information than he will find in this volume if he is to acquire a serviceable knowledge of modern power plant.

Questions and Answers on Batteries and Battery Charging. By E. MOLLOY. George Newnes, Limited, Southampton-street, London, W.C.2. [Price 5*s.* net.]

THIS book is intended to provide essential information and data regarding batteries and battery charging in a convenient question and answer form. It covers the characteristics, differences and uses of both primary and secondary cells, while the voltage and capacity of batteries, the preparation and use of electrolytes, and the employment of the hydrometer are also dealt with. Battery charging is gone into in some detail in a separate section, and the concluding pages are devoted to battery re-plating, with special reference to automobile batteries. The information is well set out and, where necessary, is clearly illustrated. We have noted no inaccuracies, although the answer to the question "What are the chief differences between lead-acid and alkaline batteries?" might have included a reference to constructional details. Naturally, too, the book suffers from the inherent weaknesses of this method of presentation. These include a little repetition, occasional undue emphasis, and some omissions. It should, however, form a useful addition to the more orthodox text-book; and can be well employed in this way both by examinees and those actually engaged in practice.

JUNIOR INSTITUTION OF ENGINEERS.—A symposium on "Railways" was given by four speakers before the Junior Institution of Engineers, on Friday, January 16, 1948, with Mr. R. A. Riddles, C.B.E., President, in the chair. Mr. G. F. Kent, speaking on permanent way, described transition curves and two-level chairs, which enabled speed limits to be increased, the system of measured-shovel packing, building up of points and crossings by oxy-acetylene welding, the use of flat-bottomed rails, and the prefabrication of track. Mr. C. R. H. Simpson spoke on "The Future of Steam Locomotives," which he regarded as assured for many years. He believed that availability and utilisation would be improved, and the conventional steam locomotive would be improved in detail. Mr. N. Newsome showed some slides of carriages and wagons, and described the designs, and Mr. A. G. Hopking advanced arguments in favour of electric traction.

THE LATE MR. J. H. DONCASTER.—We note with regret the death of Mr. James Henry Doncaster, which occurred at his home at Dore, near Sheffield, on January 16. Mr. Doncaster, who was in his 75th year, was until his retirement some years ago, chairman of Messrs. Daniel Doncaster and Sons, Limited, steelmakers, Sheffield. He was a great-grandson of the founder of the firm, and, after education at Oliver's Mount School, Scarborough, and King's College, Cambridge, he entered the family business in 1895. Some years later he was elected to the board and after serving as secretary for 20 years, was elected chairman in 1931. He was chairman of the High-Speed Steel Association for many years, and was also a former President of the Sheffield Crucible Steelmakers' Association. From 1916 until 1940 he was a member of the Council of the University of Sheffield, and was a former treasurer and Junior Pro-Chancellor. He was also for many years a member of the Sheffield Education Committee and a director of the Sheffield and District Gas Company.

LABOUR NOTES.

REPRESENTATIVES of the Passenger Section of the Transport and General Workers' Union last week presented a wage claim on behalf of 55,000 to 60,000 road-traffic employees of the former London Passenger Transport Board to representatives of the new London Transport Executive. London Transport Executive, in a statement issued later, said that the main headings of the claim were for an increase in wages, a reduction in the differential between wage rates, the payment of the same rate to conductors as to drivers, an increase in the rate for Sunday work from time and a quarter to time and a half, and the payment of time and a half to drivers and conductors for Saturday duties which finish after 6 p.m. The application is to be considered and a further meeting held to discuss it.

The Interim Report of the T.U.C. on the Economic Situation is discussed by Mr. Arthur Deakin, the general secretary of the Transport and General Workers' Union in a long article contributed to the January issue of the organisation's *Record*. Towards the end of it, he says:—"The views of the General Council, as expressed in the interim report, have been criticised in various quarters. In some cases, we have been asked why we regard it necessary to consider questions of wages, prices, and subsidies at this particular moment. Very clearly, the trade unions have a duty. Our Labour Government has made substantial efforts to bring about that measure of stability which will enable the country to move towards economic recovery . . . Another facet of the problem is that the Trade Union Movement has been asked by the Government to consider these matters as being of such importance as to merit the fullest and most complete consideration by the T.U.C. We shall not find any solution to our present difficulties by burying our head in the sand and refusing to face up in a realistic way to the intricate and serious problems confronting the country at this time."

"My own view," Mr. Deakin continues, "has been expressed repeatedly, and I should again give it emphasis. I would say to our members that the chief aim of our Movement, at this time, should be to give whatever consideration is possible towards the solution of the economic difficulties facing the country. Greater effort is necessary on the part of everyone, and increased production. Supplies of goods must be made more plentiful so as to reduce costs and make wages of greater value, thus enabling the people to buy those goods and services which are necessary to develop stability and to realise a higher standard of life." Mr. Deakin, it may be added, is a member of the General Council of the Trades Union Congress.

The Ministry of Fuel and Power states that absenteeism in the coal-mining industry during the week which ended on January 3 was higher than during the previous week. Among men at the coal face, voluntary absenteeism was 15·48 per cent., compared with 11·62 per cent., and involuntary absenteeism 6·76 per cent. compared with 5·90 per cent. Taking all employees, the percentage of voluntary absenteeism was 11·40, compared with 8·27, and the percentage of involuntary absenteeism 5·65 compared with 4·82. Output per man-shift at the coal face was 2·83 tons. This was 0·03 tons higher than in the previous week but overall output was unchanged at 1·03 tons.

Of 143 disputes leading to stoppages of work, reported to the Ministry of Labour and National Service as beginning in November, 20, directly involving 13,400 persons, arose out of demands for advances in wages; 36, directly involving 4,400 persons, arose out of other wage questions; 4, directly involving 3,200 persons, arose out of questions relating to working hours; 20, directly involving 3,600 persons, arose out of questions respecting the employment of particular classes or persons; and 40, directly involving 7,500 persons, arose out of other questions relating to working arrangements. Three stoppages, directly involving 3,000 persons, were in support of employees involved in other disputes.

"We are advised," Mr. Tanner states in the January issue of the Amalgamated Engineering Union's *Journal*, "that the Ministry of Transport has received a report from the British Consul at Bremen about the position of merchant seamen who miss their ships there, and of which, executive council feel, sea-going members should be warned. The report states that, although no British seamen have been sentenced for illegal entry, the United States authorities have decided, in view of the numbers of seamen who have missed their ships, to tighten up the regulations. In future, any seaman of any country found ashore after the departure of his ship will be sentenced to a minimum of 30 day's imprisonment; and exceptions will only be made in favour of those who can show a really valid excuse, as, for instance, that the sailing time was put forward without their knowledge. Shore leave passes will be timed to expire four or six hours before the estimated time of departure of the ship."

The membership of the Amalgamated Engineering Union at the end of December, as indicated in returns received at the General Office from branches, was 822,416—a decrease of 5,339 compared with the position at the end of November. During December, 5,355 members were paid sick benefit—a decrease of 84—and 908, unemployment benefit—a decrease of 22. Superannuation payments were made to 20,082 members—an increase of 102—and the total number of unemployed members remained unchanged at 3,120.

Mr. Tanner, whose current term of office as President of the Amalgamated Engineering Union will shortly expire, has been nominated for re-election. Five other members of the union have accepted nomination and been declared eligible to contest. They are: Mr. J. Johnston (Newcastle Branch), Mr. C. Morling (Erith 3rd Branch), Mr. W. A. Price (Sunderland 5th Branch), Mr. W. Shaw (Belfast 18th Branch), and Mr. R. Veal (Romford Branch). The last day for voting is March 15, and the results must reach the General Office not later than March 17.

Mr. Gardner, the general secretary of the Amalgamated Engineering Union, says in the January *Journal* that members who undertake authorised day training in Technical Schools or Colleges, or preparatory examinations of a technical character by virtue of which they are unable to follow their normal occupations may be deemed to be unemployed and covered by Rule 26, clause 4, which reads:—"Where a member is preparing and sitting for a Board of Trade examination, he shall be entitled to unemployment benefit, according to the Section of which he is a member." A necessary proviso, it is added, is that their monetary grants and emoluments must not equal their district rates of wages.

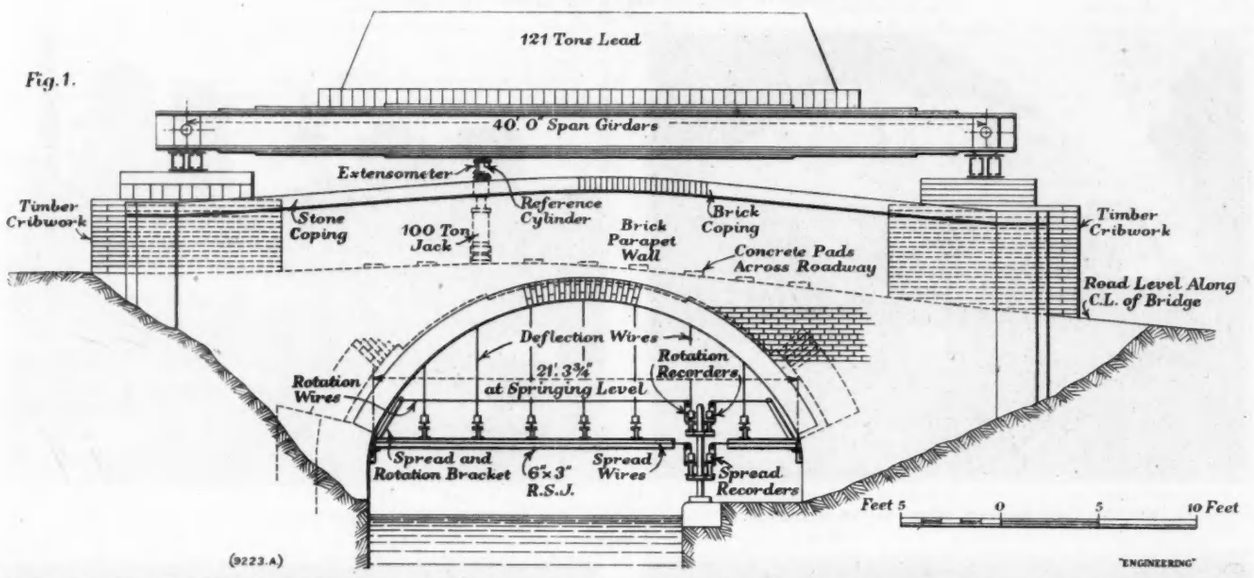
The executive council of the Amalgamated Engineering Union has entered into an arrangement with the Institute of Patentees, under which service is rendered to members who have inventions or original ideas in connection with them. The service, it is explained, will be of an advisory nature on all matters relating to patents, and an opinion on an invention when it is protected by the filing of a Provisional or a complete specification. Members who desire to take advantage of the service may write direct to "The Secretary, the Institute of Patentees, 207-208, Abbey House, Victoria-street, Westminster, S.W.1," but their applications must be accompanied by a note signed by their branch secretary and bearing the seal of the Branch certifying that the applicant is a member of that Branch of the A.E.U. The arrangement does not include the services of their Commercial Department which, however, can be engaged as a personal matter by the inventor, if his idea reaches the stage of negotiations for turning the invention to commercial advantage. The arrangement is for two years and will be reviewed prior to the end of that period.

The Wool and Allied Trades Employers' Council are considering a wage claim affecting about 186,000 persons in the wool textile trades. It is a consolidated application by the various unions which have members employed in the industry and is for an increase of 15 per cent. in time rates and one of 10 per cent. in piece rates. In support of it, the unions claim that the average earnings in the trade are relatively low compared with those of a considerable number of other industries.

DANISH INSTITUTION OF CIVIL ENGINEERS.—In the spring of 1945, the headquarters of the Danish Institution of Civil Engineers (Dansk Ingeniøforening) in Copenhagen was totally destroyed by the Royal Air Force, together with an adjoining building which was being used by the Gestapo. This headquarters has now been rebuilt, and its opening was duly celebrated on Wednesday and Thursday, January 21 and 22. An invitation to be present on the occasion was received by the Institutions of Civil, Mechanical and Electrical Engineers, who asked Sir Stanley Angwin to act as their delegate. Sir Stanley was also asked to convey the cordial wishes of their fellow professional engineers in this country to the Danish engineers. The celebrations included the unveiling of a memorial to Danish civil engineers who gave their lives during the war for the freedom of Denmark.

TESTING OF HIGHWAY BRIDGES.

Fig. 1.



TESTING OF HIGHWAY BRIDGES.*

By DR. N. DAVEY, M.I.C.E.

IN 1936, the Building Research Station commenced an investigation into the behaviour under load of various types of highway bridge, more especially those of the masonry-arch type and the cast-iron girder type up to about 40-ft. span. Many hundreds of these bridges exist throughout the country. They were built mainly during the periods of canal and railway construction in the late Eighteenth Century and the first half of the Nineteenth Century, respectively, and carry to-day very much heavier traffic than that for which they were originally intended.

In 1933, the owners of bridges were empowered to restrict the maximum weight of vehicles permitted to cross any given bridge, and did so on the basis of methods of strength assessment then thought appropriate. Experience showed, however, that vehicles much in excess of the permitted weight could traverse the bridge without apparent ill effects. It was obvious, therefore, that the methods used in assessing the load-carrying capacity of bridges were unduly conservative, and the research undertaken by the Building Research Station, on behalf of the Ministry of Transport, was intended to investigate the source of the unsuspected strength of such bridges and hence to lead to more accurate methods of estimating their load-carrying capacity. Between 1936 and the outbreak of war, when the programme was temporarily discontinued, many loading tests were made on selected bridges. A few bridges, details of which are given in Tables I and II, herewith, were loaded to destruction. Others were tested at various stages during demolition in order to determine the dispersion and distribution of an applied load, and the strengthening effect of parapet walls, spandrel walls, filling, etc.

In the case of the bridges tested to destruction, the load was applied by means of hydraulic jacks. The thrust of the jacks was taken on two 40-ft. steel girders placed about 7 ft. apart, parallel to the centre line of the roadway, and supported on timber cribs beyond each abutment, as shown in Fig. 1, herewith. The girders carried a timber platform upon which was placed pig lead or cast iron. The load transmitted to the bridge was measured by means of proving rings inserted between the jacks and the girders of the loading platform. Before the final loading test, other tests were made to study the distortion of the structures under loads of varying intensity, applied at selected positions. In the case of the arches, vertical deflections were measured at the eighth points of the span on the centre line of the bridge and also at each side. Transverse spread at the crown, longitudinal spread of the arch, rotation of the abutments, and strain readings at various points on the intrados and extrados were observed. A typical test arrangement is shown in Fig. 2, on page 94. The tests on the cast-iron girder bridges comprised measurements of the deflection of the beams, and the strains in their upper and lower flanges. The typical test arrangement for a bridge of this type is shown in Figs. 3 and 4, on page 94.

In 1942, the problem had again become an important and urgent matter. The Ministry of Supply wished to classify all bridges according to their military load-carrying capacity, and the Building Research Station was asked by the Ministry of War Transport to make a series of tests on a selection of typical cast-iron girder and masonry-arch bridges to determine the strains and deflections produced by representative military vehicles of various weights. The results of these tests were used as a basis for the assessment of similar types of bridge throughout the country. Some tests were also made on a certain number of other bridges the assessment of which, according to the methods in use, was in doubt, and where it was desired, therefore, to have a check on the actual strains produced. In all cases, the method of test was to bring the loading vehicle into position on the bridge and to measure, by

TABLE I.—ARCH BRIDGES TESTED TO DESTRUCTION.

Date of Erection.	Location.	Description.	Dimensions.		Maximum Load Applied, Tons.	Remarks.
			Span.	Width.		
1793	Over disused Derby Canal at Breadsall, Derby.	Sandstone voussoirs about 14 in. deep ..	Ft. In. 21 2	Ft. In. 17 9 (at crown)	77·6	Arch collapsed with 38·8 tons on each of two jacks at crown of arch.
1793	Over Stratford-on-Avon Canal, Yardley Wood Road, Birmingham.	Bonded brick ring; varying thickness 13 in., 14½ in., 18½ in.	21 2	14 8 (at crown)	123	Arch collapsed with 61·5 tons on each of two jacks at crown of arch.

TABLE II.—CAST-IRON GIRDER BRIDGES TESTED TO DESTRUCTION.

Date of Erection.	Location.	Description.			Dimensions.							Maximum Load Applied.	Remarks.
		Number of Girders.	Inter-Girder Construction.	Material of Fill.	Clear Skew Span Between Front Edges of Bearings.	Average Square Spacing of Girders at Midspan.	Angle of Skew.	Square Width Between Centres of Webs of Outer Girders.	Maximum Overall Depth at Midspan.	Depth of Girder.	Section Modulus of Internal Girders at Midspan.		
					Ft. In.	Ft. In.	Deg.	Ft. In.	Ft. In.	Ft. In.	Inch Units.	Tons.	
1848	Over disused Newmarket-Chesterford Railway, Babraham, Cambs.	7	Brick jack arches	Mixed	30 3	6 5	33	21 3½	2 7	2 0	501	58	Bridge failed with 58 tons on a single jack at centre of bridge.
1855 (about)	Over River Ouse, near Oakley, Beds.	4	do.	do.	35 6	4 1	2	12 7	2 8	2 1	642	115	Bridge failed with 57½ tons on each of two jacks at centre of span.
1870	Over stream in Great Baddow, Essex.	7	Cast-iron plates	do.	13 0	2 10	0	16 3	1	1 0	83	74·6	Bridge failed with 37·3 tons on each of two jacks at centre of span.

* Paper presented at the Public Works, Roads and Transport Congress, in London, on July 23, 1947, by permission of the Director of Building Research. Crown copyright reserved. Abridged.

TESTING OF HIGHWAY BRIDGES.

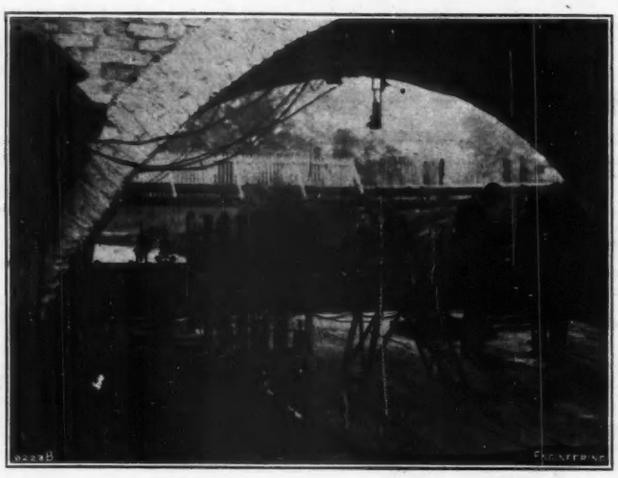


FIG. 2. TEST ARRANGEMENT FOR ARCH BRIDGE.

FIG. 3. TEST ARRANGEMENT FOR CAST-IRON GIRDER BRIDGE.

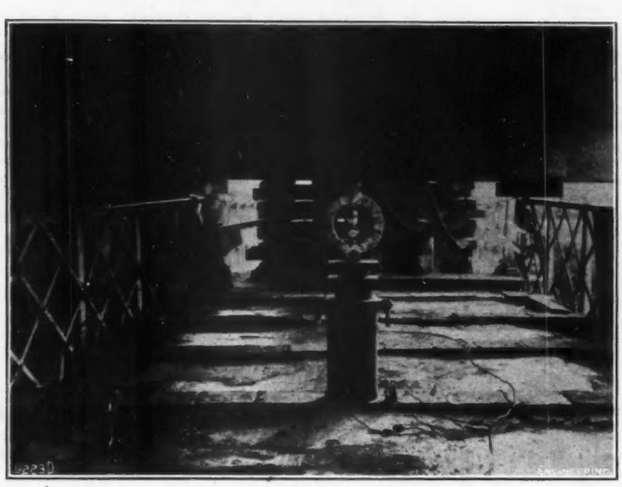


FIG. 4. CAST-IRON GIRDER BRIDGE UNDER TEST.

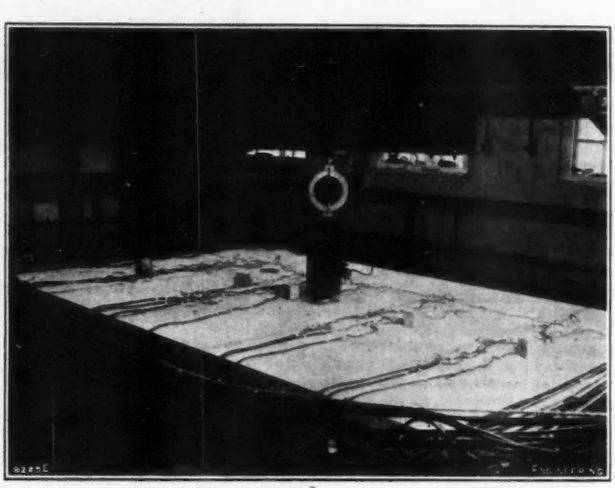
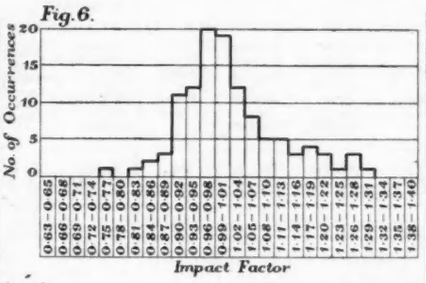


FIG. 5. LARGE-SCALE BRIDGE MODEL UNDER TEST.

means of appropriate instruments, the deflection or strain, or both, at certain selected points. As a result of the work, much higher military load classifications were given to many bridges, and it was also found possible to suggest an approximate method of classifying cast-iron bridges for emergency use in the field.

The experience and knowledge gained both in the pre-war and war-time tests on the cast-iron girder type of bridge showed that, not only do the fill and jack arches serve to distribute the load quite effectively from a loaded girder to those farther from the load, but they also behave as though they formed the compression flange of a T-beam, of which the tension flange is formed by the lower part of the cast-iron girder itself. This T-beam action appears to be due to the consolidation of the fill over a period of years, and to the development of a good bond between the fill and jack arches and the girder. The result is that, if the strengthening and distributing action of the fill is taken into account, the stresses so calculated are much lower and much nearer to the observed values than are those calculated on the basis of previous methods of assessment. Unfortunately, the variability of the materials and the behaviour of different bridges is such that it has not been possible to obtain exact agreement between the calculated and the observed values, but it has been possible, nevertheless, to obtain formulæ which will indicate the minimum strength of a given cast-iron girder bridge and which have resulted in increased assessments of a large number of bridges. The most important departure from the earlier methods of calculating live-load stresses, agreed to by the Ministry of Transport and the railway companies of Great Britain, was to consider the effective section modulus of the composite beam—that is, the girder with those portions of the jack arches, filling material,

Fig. 6.



(9223f) "ENGINEERING"

and road material which are bounded by the vertical line through the crown of the jack arch on each side of the girder—as equal to that of the bare girder multiplied by a factor $\frac{D}{d}$, where D denotes the overall depth of the bridge and d the depth of the girder at mid-span. In addition, to determine the actual load carried by one girder, the appropriate distribution coefficient is taken as $\frac{S}{72}$, where S is the girder spacing in inches. Where the girder spacing exceeds 72 in., the value of S should be taken as 72.

Thus, if Z in.³ is the section modulus of the bare girder at midspan, S inches is the girder spacing, measured square to the girders, and M inch-tons is the calculated maximum bending moment produced by the total load on the bridge, including any impact allowance, then the live-load stress f for a tracked or wheeled vehicle of the normal type is given by:

$$f = \frac{MS\,d}{144\,ZD} \text{ tons per square inch.}$$

If the vehicle is of a type which has many wheels per axle, distributed across the width of the vehicle and tending to produce a line load on the most heavily laden axle of width L in., the formula becomes:

$$f = \frac{MS\,d}{144\,ZD} \times \frac{2S}{L} \text{ tons per square inch.}$$

$$\left(\text{The factor } \frac{2S}{L} \text{ must not exceed a value of } 2\right).^{*}$$

It is necessary to bear in mind that the condition of the cast-iron girders in a bridge is rarely known; that the occurrence of blowholes and slag inclusions is frequent; and that, even if their presence has been detected, it is not possible to determine the consequent reduction in strength of the girder. Moreover, instances of the discovery of unsuspected cracks are on record. In view of these considerations, it appeared doubtful whether the permissible stress for normal conditions of loading should be allowed to exceed 2·5 tons per sq. in. It is hoped to carry out, in the near future, some fatigue tests on typical cast-iron girders which have been removed from bridges undergoing reconstruction. However, evidence from other sources indicates that cast-iron has a high fatigue stress and freedom from notch sensitivity, and, if this is confirmed by the fatigue tests which are to be carried out

* A fuller account and discussion of this work was recorded in the *Jl.Inst.C.E.*, vol. 22 (8), pages 243-307 (1944).

at the Building Research Station, fatigue may not be so important as was commonly supposed.

Although, during earlier tests, there had been some observations of the deflection of bridges while heavy traffic was traversing them, there had been no opportunity of observing the strains produced by these dynamic loadings. The growing incidence of heavy tracked vehicles, such as tanks, and of exceptionally heavy civil loads, caused some concern as to the magnitude of the impact effects produced by such vehicles and, at the request of the Ministry of War Transport, a programme of work on this problem was begun in 1944. The investigation is still proceeding; but the tests already made and the tentative conclusions drawn from them will be described briefly.

Various vehicles have been used, including steam rollers, a 19-ton lorry with pneumatic tyres, a solid-tyred Scammell lorry, a Churchill tank, and a Diamond-T transporter carrying a Churchill tank. The bridges on which the tests were made were of typical cast-iron girder and brick jack-arch construction. A comparison was made between the peak value of the strain produced at midspan of the lower flange of a girder, as a particular vehicle crossed the bridge at uniform speed, with the peak value produced at the same point for static loading due to the same vehicle.

The strain gauges used were of the vibrating-wire type. The gauges were used in combination with a reference instrument of fixed frequency, so that the electrical impulses from each gauge and the reference instrument were superimposed one upon the other to produce beats having a frequency equal to the difference between the frequencies of the respective instruments. Thus changes in the frequency of the test gauge caused by variations in strain resulted in changes in the beat frequency. These changes were recorded by means of a cathode-ray oscillograph and cine-camera, and a continuous photographic record was thus obtained of the varying strains at a given point on the bridge while a vehicle crossed it.

Examination of the test results so far obtained shows a wide range of impact factors for runs which were apparently identical as regards the bridge and girder tested and as regards type, position and speed of the vehicle. In view of the number of variables involved and the amount of scatter of the results, the number of observations made is relatively small, and it is not possible yet to draw other than general conclusions; in particular, it has not been possible to ascertain whether there is any change in the impact factor with increasing speed. Fig. 6, opposite, however, shows the number of observations of the impact factor which lie within given limits of value. It will be seen that the most frequently occurring values are within the range 0·96 to 0·98. Higher values than unity do occur, but not so frequently.

The investigations on the cast-iron girder type of bridge showed that there was a considerable distribution of load, only a fraction of the applied load getting through to the girder immediately beneath it in that system of construction; and it became apparent that, possibly, similar effects would be observed in the case of bridges with steel girders, particularly those with jack arches. If this were found to be so, a considerable saving in steel would result, as in present methods of design it was usual to assume no distribution of load. A fundamental investigation was started, therefore, in conjunction with the Ministry of Transport, to determine the behaviour of composite bridge-deck systems. The main types being considered are (*a*) steel girders supporting a reinforced-concrete slab; (*b*) as (*a*), except that the girders are encased in concrete; (*c*) steel girders with concrete jack arches supporting a reinforced-concrete slab; and (*d*) filler-joist slab.

In each case, the primary object will be to find the distribution of stress throughout the system for any combination and position of concentrated loads (representing wheel loads) so that economical designs can be prepared for future bridges. The work will be divided into several parts. Firstly, an attempt is being made to calculate the behaviour of various types of bridge under a concentrated load. The mathematical analysis, however, is complicated and lengthy, and, in an attempt to obtain quicker results, small models are being tested. These are being built of steel units, so that their behaviour is wholly elastic at low loads and their distortion should agree closely with that calculated on the elastic theory. Since reinforced concrete does not behave elastically, these small models (and the calculations) may not be completely applicable to the actual bridge construction. Larger models are therefore to be built with materials similar to those used in practice. The first of these larger models, corresponding to type (*a*) above, has already been made and tests carried out. The model consists, as shown in Fig. 5, opposite, of six girders on a span of 9 ft., supporting a reinforced-concrete slab approximately 15 ft. wide. Measurements made include deflections of the slab and girders, and the strains at a large number of positions throughout the system.

DIESEL ENGINES UNDERGROUND.*

By L. B. BERGER, M. A. ELLIOTT, JOHN C. HOLTZ and H. H. SCHRENK.

(*Continued from page 55.*)

THE concentrations of oxides of nitrogen found before and after the exhaust gas had passed through the water in the cooling boxes are of interest, as they indicate that only a small proportion of the oxides of nitrogen was removed by the action of the water. It seems probable that in continued operation equilibrium would be established between oxides of nitrogen in the exhaust gas and oxides of nitrogen dissolved in the water, with the result that the concentration of these gases would not be decreased significantly by passage through the water in the cooling boxes.

The concentration of aldehydes in the exhaust was not determined in these tests. The odour of aldehydes was evident in the final exhaust, and samples of water from the cooling boxes showed the presence of dissolved aldehydes, indicating that passage through water removed some but not all of the aldehydes. The exhaust-cooling boxes, therefore, proved more effective in reducing the temperature of the exhaust gases than in removing objectionable constituents of the exhaust.

In the final (diluted) exhaust of the locomotive, carbon monoxide did not exceed 0·01 per cent. Oxides of nitrogen were not determined in the final exhaust, but their concentration could be calculated, approximately, from the dilution of the engine exhaust indicated by the ratio of the carbon-dioxide content of the engine exhaust to that of the final exhaust. Results of these estimates are as follows:

	Test.						
	1	2	3	4	5	6	7
Oxides of nitrogen in cooled exhaust, p.p.m.	117	358	274	444	232	805	589
Oxides of nitrogen in final exhaust (estimates), p.p.m. ...	13	41	—	39	—	63	51

These calculations indicate also that the engine exhaust was being diluted with 8 to 12 times its volume of air before being discharged from the locomotive. Consideration of these data on carbon monoxide and oxides of nitrogen, together with the observed carbon dioxide and oxygen contents of the final exhaust, indicated that locally hazardous conditions would not be created by passage of the locomotive through a properly ventilated place.

To arrive at an estimate of the minimum quantity of ventilation that would be required in the tunnels of the Aqueduct, the production of carbon monoxide, oxides of nitrogen, and carbon dioxide was used as the basis of calculation. The following procedure was used:

1.—The volumes of carbon monoxide, oxides of nitrogen, and carbon dioxide produced per unit time in each test were obtained by multiplying the piston displacement of the engine per unit time by the concentration of the exhaust gas constituent in question.

2.—From the quantities obtained in operation (1), the maximum volume of each of the three constituents was selected. The quantity of ventilating air required per unit time was calculated from these maximum volumes by use of the relation

$$Q = \frac{100\ V_{max.}}{Y}$$

in which

Q = volume of ventilating air required, cubic feet per minute,

$V_{max.}$ = maximum volume of the particular constituent under consideration, cubic feet produced per minute,

Y = maximum permissible concentration of the constituent under consideration, per cent. by volume.

At the time these tests and calculations were made, the following concentrations were generally considered as the maximum permissible in the air of underground working places: carbon monoxide, 0·01 per cent. by volume; oxides of nitrogen, 0·004 per cent. by volume; and carbon dioxide, 1·0 per cent. by volume. Since that time lower values have been suggested for oxides of nitrogen and for carbon dioxide.

3.—The maximum quantity of ventilating air per minute indicated by operation (2) was taken as the minimum ventilation quantity that should be in effect when the Diesel locomotive was put into service underground.

TABLE III.—CALCULATION OF MINIMUM QUANTITY OF VENTILATION ACCEPTABLE IN CONNECTION WITH UNDERGROUND USE OF DIESEL LOCOMOTIVE. CALCULATIONS BASED ON PRELIMINARY TESTS OF FIRST LOCOMOTIVE.

Operation 1.

Test No.	Piston Displacement, Cub. Ft. per Minute.	Concentration of Toxic Constituent in Exhaust Gas, Per Cent. by Volume.			Volume of Toxic Constituent Produced, Cub. Ft. per Minute.		
		Carbon Monoxide.	Oxides of Nitrogen.	Carbon Dioxide.	Carbon Monoxide.	Oxides of Nitrogen.	Carbon Dioxide.
1	108	0·08	0·0101	1·96	0·086	0·011	2·12
2	143	0·03	0·0388	5·46	0·043	0·055	7·58
3	163	0·02	0·0356	5·27	0·033	0·058	8·59
4	347	0·03	0·0476	8·28	0·104	0·165	28·72
5	352	0·04	0·0315	2·95	*0·141	0·111	10·39
6	183	0·03	0·0996	10·55	0·055	0·182	19·30
7	327	0·02	0·0715	11·14	0·065	*0·234	*36·42

Operation 2.

Maximum Volume of Toxic Constituent Produced, Cub. Ft. Per Minute (from Operation 1).			Quantity of Ventilating Air Required to Dilute Toxic Constituent to Permissible Concentration, Cub. Ft. per Minute.		
Carbon Monoxide.	Oxides of Nitrogen.	Carbon Dioxide.	Carbon Monoxide.	Oxides of Nitrogen.	Carbon Dioxide.
0·141 (Test 5)	0·234 (Test 7)	36·42 (Test 7)	1,410	*5,850	3,642

Operation 3.

From operation 2 it is evident that, in this instance, production of oxides of nitrogen is the controlling factor in estimating ventilation requirements, and that at least 6,000 (5,850) cub. ft. per minute of ventilating air must be supplied.

* Significant value.

The calculations involved are given in Table III, based upon data from Tables I and II on page 55, *ante*. The results of these calculations showed that production of oxides of nitrogen was the controlling factor in estimating ventilation requirements, and that at least 6,000 cubic feet of ventilating air per minute would be required to dilute the exhaust of the locomotive to an extent that would reduce the oxides of nitrogen to a concentration permissible in the air of working places. Accordingly, this ventilation rate (6,000 c.f.m.) was recommended as the minimum ventilation that should be in effect when the first locomotive was put into service underground.

Upon the basis of observations made while the Diesel locomotives were used in construction of the Delaware Aqueduct, it was suggested that the maximum rated power output of an engine may be used in calculating the quantity of ventilation that should be supplied and that 75 cubic feet of air per minute per horsepower will furnish adequate ventilation when operating a Diesel engine in normal air. It should be recognised, however, that this recommendation is based upon experience with but one type and make of engine, which was used in tunnels in which normal air was present. Other recommended values for ventilation based upon engine horse-power are 212 cubic feet per minute per horse-power in Germany, 159 cubic feet in France, and 225 cubic feet per minute in England. The differences in these values indicate either that there was considerable variation in production of toxic gases by the different engines studied, or there were

* Reprinted from Report of Investigations, No. 4032, United States Bureau of Mines. (Abridged.)

differences in the composition of the surrounding air, or there is lack of agreement as to the desirable extent of dilution of the toxic constituents of the exhaust. Any scheme for estimating the ventilation required for an engine must depend fundamentally upon knowledge of the rate at which the toxic constituents of the exhaust are produced by that engine. The estimate of minimum required ventilation illustrated in Table III was made on this basis.

On one of the contracts of the Delaware Aqueduct where Diesel locomotives were installed, they were used for any purpose involving haulage; on the other contract they were used only in hauling concrete during the tunnel-lining operation. In tunnel-driving, the main use of the Diesel locomotives was in hauling spoil from the face to the shaft bottom and in returning empty spoil cars to the face. During the operation, the gross weight moved per loaded trip averaged about 100 tons, although it is reported that occasionally much heavier loads were moved by the Diesel locomotives. In the tunnel-lining operation, the locomotives were used to haul concrete from the shaft bottom to the points where the lining was being placed. The gross weight moved per loaded trip in hauling concrete was about 80 tons, and haulage speeds of 18 to 20 miles per hour were attained.

On the contract where the Diesels were used during tunnel-driving, two systems of ventilation were employed. The first installation consisted of a pressure, or blowing, system, in which air was delivered from the surface to a point near the working face of the tunnel through sheet-steel tubing, 24 in. to 26 in. in diameter. The ventilating air travelled from the face back through the tunnel bore and was discharged through the shafts to the surface. With this system, about 6,000 cubic feet of air per minute could be delivered to each of two headings driven in opposite directions from a shaft. While this system was in effect, the direction of ventilation was reversed just before blasting, so that powder smoke would be drawn out of the heading at the face and would not traverse the whole length of the tunnel bore to the shaft. Exhaust ventilation was continued until most of the powder smoke was removed from the face area, and then pressure ventilation was restored.

This pressure system of ventilation was replaced, after the tunnels had been developed to a considerable length, by an exhaust system of ventilation. With this system the tunnel air was withdrawn from the face area through the vent pipes, and an auxiliary blower of 3,000 or more cubic feet per minute capacity was installed in the tunnel with its intake several hundred feet from the tunnel face and its discharge delivered into the face area through flexible tubing. When this system was installed, the capacity of the main ventilating plant was increased, so that 10,000 to 11,000 cub. ft. of air per minute could be withdrawn from each tunnel heading.

When tunnel driving was completed, and the various headings were "holed through" to form a continuous system vented to the surface by two or more shafts, the quantity of ventilation through the tunnels was greatly increased, as natural ventilation was set up by differences between underground and surface air temperature. At seasons of the year when ground temperature and surface air temperature might be the same, natural ventilation was augmented by axial-flow fans mounted in bulkheads situated in the tunnel at suitable points between the shafts. While tunnel lining was in progress with this system of ventilation in effect, air flow through the tunnels ranged approximately from 20,000 to 90,000 cub. ft. per minute.

(To be continued.)

CATALOGUES.

Internal Grinding Machines for Cylinders.—The Churchill Machine Tool Company, Limited, Broadheath, Manchester, have issued a pamphlet on their internal cylinder-grinding machines. In addition to straightforward work up to 10 ft. in depth, the machines can be used for grinding internal valve seatings, and other awkward jobs. Single-head and double-head machines are available.

Monotower Cranes.—The cranes described in a catalogue received from Messrs. Butters Brothers and Company, Limited, Maclellan-street, Glasgow, S.1, are of the monotower type and are used principally in shipyards, but also on civil-engineering work. They may be fixed or travelling, and the usual sizes provide for a maximum lift of 15 tons and for radii up to 125 ft. Other sizes, however, are available.

Radio-Frequency Heating Equipment.—A leaflet issued by Messrs. Pye, Limited, Radio Works, Cambridge, deals with their 3-kW and 6-kW radio-frequency heaters. The primary function of the smaller model is the speedy setting of glue lines in the making of furniture. It can, however, also be used for the manufacture of plywood and veneers, as well as for the drying of wood for seasoning and for the extraction of moisture from paper. The larger model can be employed for similar purposes where a greater output is required.

"ENGINEERING" ILLUSTRATED PATENT RECORD.

ABSTRACTS OF SPECIFICATIONS RECENTLY PUBLISHED UNDER THE ACTS OF 1907 TO 1939.

The number of views given in the Specification Drawings is stated in each case; where none is mentioned, the Specification is not illustrated.

Where inventions are communicated from abroad, the Names, etc., of the Communicators are given in italics.

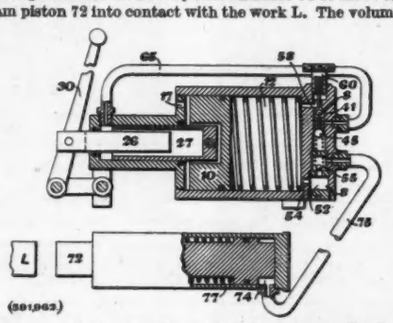
Copies of Specifications may be obtained at the Patent Office Sales Branch, 25, Southampton Buildings, Chancery-lane, London, W.C.2, price 1s. each.

The date of the advertisement of the acceptance of a Complete Specification is given after the abstract in each case, unless the Patent has been sealed, when the word "Sealed" is appended.

Any person may, at any time within two months from the date of the advertisement of the acceptance of a Complete Specification, give notice at the Patent Office of opposition to the grant of a Patent on any of the grounds mentioned in the Acts.

HYDRAULIC APPARATUS.

591,962. Hydraulic-Pressure Generator. H. E. Page, Alhambra, California, U.S.A. (2 *Figs.*) March 12, 1945.—The invention is a hydraulic device for generating pressure first at high volume and low pressure to bring a hydraulic ram into initial contact with the work to be pressed, and then automatically to generate a high pressure at a low volume for performing the work. To make initial contact between ram piston 72 and the load L, lever 30 is first moved to the left, which causes plunger 26 to create a vacuum in chamber 27, thus drawing fluid from chamber 12 past valve 41 through conduit 65. Then forward movement of lever 30 moves piston 26 into chamber 27, and since the fluid cannot return to chamber 12 past valve 41, and since, prior to the time the ram piston 72 makes contact with its load, the pressure is insufficient to unseat valve 45, the fluid thus will be trapped in chamber 27 so that further inward movement of piston 26 will move piston 10 to the right in chamber 12, forcing fluid out through port 54, chamber 52, past valve 55, and through conduit 75 directly into chamber 74 to move the ram piston 72 into contact with the work L. The volume-

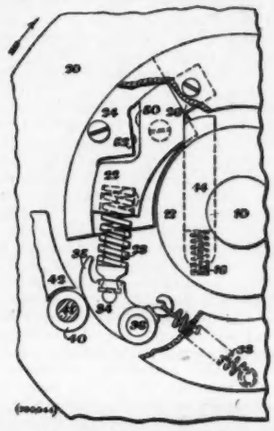


(591,962)

pressure ratio in chamber 12 is thus such as will effect rapid movement of the ram piston until it engages the load. When the load L is touched by the piston 72, further reciprocation of piston 26 will, on each suction stroke, draw fluid from chamber 12 as described, and on each pressure stroke this fluid will be forced past valve 45 and through conduit 75 into chamber 74, since the pressure in chambers 27 and 58, by virtue of resistance to movement of the ram piston 72 offered by the load, will be sufficient to unseat valve 45 against its relatively strong spring. As during this portion of the operation the pressure in chamber 27 is greater than that in chamber 12, ball 55 will remain seated. On each withdrawal of fluid from chamber 12, sufficient vacuum will be created in it to cause piston 10 to move to the right, the opposite face of piston 10 being exposed to atmospheric pressure through port 17. Since the left face of piston 10 is exposed to atmospheric pressure, it will not move to the left on each outward stroke of plunger 26. To release pressure in ram chamber 74, the valve-actuating device 60 is screwed inward to cause unseating of valves 41 and 45, which permits the ram piston 72 to move to the right under the influence of spring 77, forcing fluid from chamber 74 through conduit 75 and bore 8 into chamber 12, and also moving piston 10 to the left. (*Sealed.*)

MISCELLANEOUS.

590,044. Clutches. The British United Shoe Machinery Company, Limited, of Leicester, and F. B. Keall, of Leicester. (4 *Figs.*) April 11, 1945.—This invention is concerned with single-revolution clutches, particularly as applied to presses which perform a definite cycle of operations. When operated, the clutch performs a single revolution and then automatically disengages itself. The shaft 10 of the press carries a hub 12 in which is mounted a bolt 14 arranged to slide under the action of a spring 16 seated in the hub. The outer end of this bolt 14 projects, when the bolt is in the operative position, into the path of a driving member 22 mounted in the flywheel 20 of the press, which is constantly rotating in the direction of the arrow. The driving member is mounted within a recess in a segmental housing 24 rigidly fastened to the flywheel 20. The driving member 22 is normally pressed against a stop 26 by a compression spring 28, the other end of which presses on a lever 34 pivoted on a stud 36 fixed in the flywheel and provided with an inwardly curved end portion 35. A light tension spring 38 tends to pull the lever 34 in a direction to press the block 22 against the stop 26. Mounted on the frame of the press, so as not to rotate with the flywheel 20, are a roll 40, on a stud 41, and a cam plate 42. As the flywheel 20 continues its



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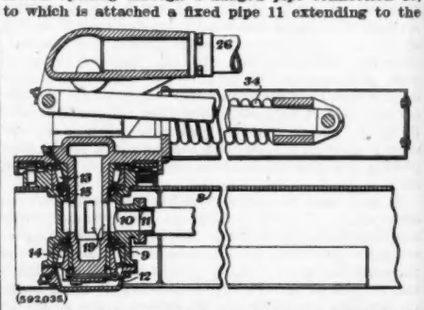
rotation, and after the faces 50 and 52 have come into contact, the lever 34 passes first off the roll 40 and then past the cam plate 42, the compression of the spring 28 pushes the lever 34 radially outwards against the pull of the light spring 38. The drive of the flywheel upon the bolt 14 will be continued through the block 22 with the faces 50, 52 of the block and housing 24 in contact. At the end of the active revolution of the press, the bolt 14 will be withdrawn automatically and the lever 34 will have been again brought round so that its incurved end portion 35 will engage the roll 40 and cause the lever to be pressed inwardly by the roller into the position shown. (*Sealed.*)

592,035. Refuelling Plant for Aircraft. Zwicky, Limited, of Slough, and L. T. Spurin, of Slough. (4 *Figs.*) May 6, 1944.—This invention relates to fuel-replenishing plant for aircraft carried upon a tanker vehicle. As at present constructed, such vehicles carry one or more booms by which a flexible filling hose may be lifted to the aircraft tank. The present invention employs one or more hollow booms, rotatable in both a horizontal and a vertical plane, which themselves form conduits for the fuel and may terminate in a sufficient length of flexible hose for making connection to aircraft tanks at different heights. Welded to the tank at its front end is a stout metal housing 8. This supports a hollow bearing shell 9 of cylindrical form, in which is a lateral opening through a flanged pipe connection 10, to which is attached a fixed pipe 11 extending to the



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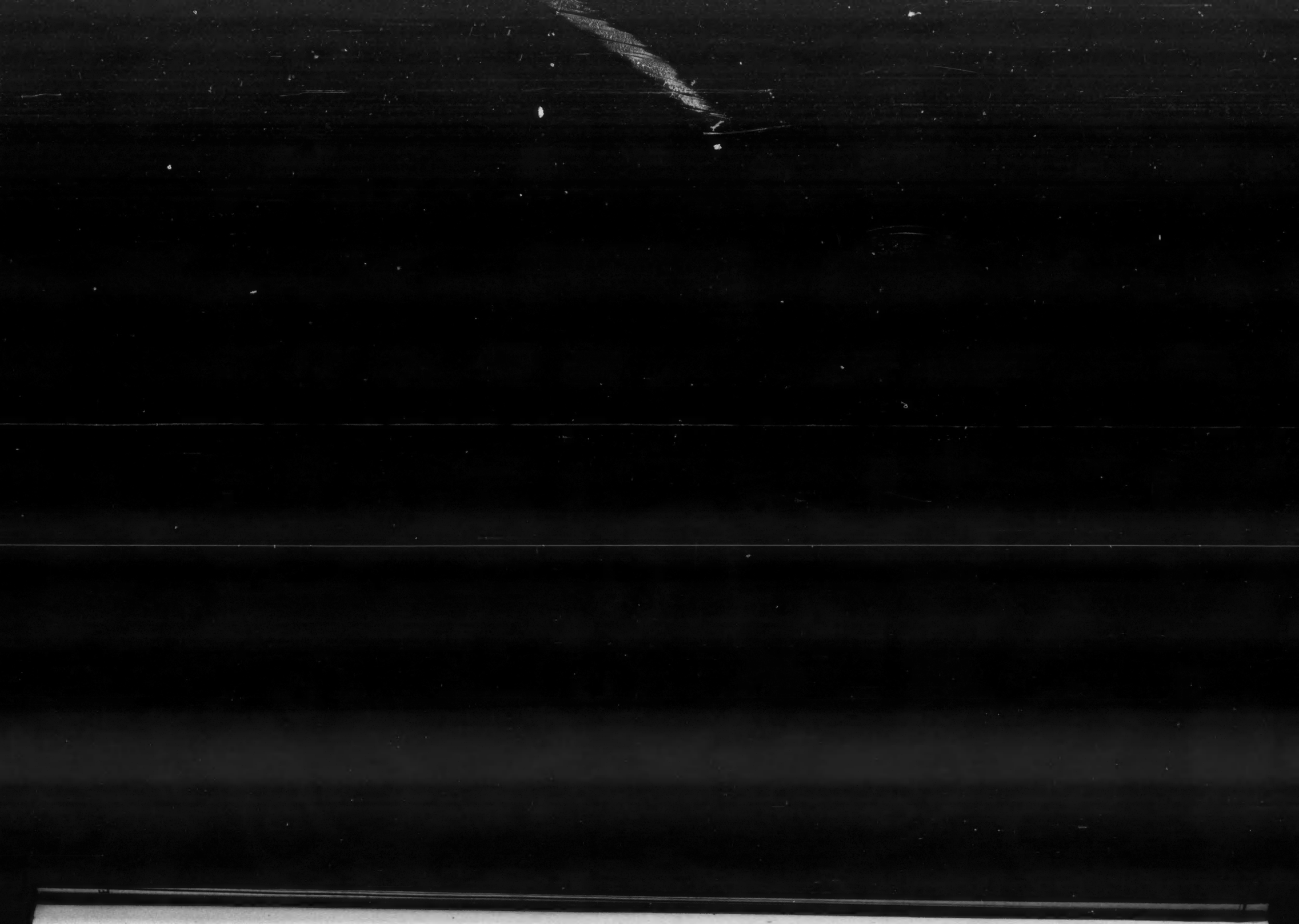
valves and pump supplying the fuel. The bearing shell 9 is open at the top, and is closed at the bottom by a cup 12. Its top and bottom ends are enlarged to receive the outer races of roller bearings 13, 14, to allow the boom to turn upon a vertical axis. In the bearings 13, 14, there rotates a spigot stem 15 carrying the inner races of the bearings. This is closed at its lower end and forked at its upper end. The stem 15 is of T-form, having horizontal hollow arms extending in opposite directions at its upper end and communicating with a box-like structure. The boom 26 is mounted on hollow trunnions rotating on roller bearings within the box, to enable it to move in a vertical plane. The fuel passes from the pipe 10, by way of the apertures 19, into the hollow spindle 15, into the box, then through the hollow trunnions into the boom 26, which terminates in a flexible hose and nozzle to enter the fuel tank of the aircraft. The weight of the boom is balanced by the spring 34. (*Accepted September 5, 1947.*)